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BRITISH SURGICAL PRACTICE

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INTRODUCTION

Our first word must be one of thanks to our contributors. Many of them began and some completed their articles in the difficult days and adverse circumstances of war, and to them we must apologize for the unavoidable delay in the appearance of their work in print.

There are many surgeons who have no easy access to libraries, works of reference, or centres of teaching and research, and it is for them especially that this work is intended. While they may have no intention of attempting the more recondite operations of the specialist, they should know what can be accomplished by the expert working with his chosen team in optimal conditions. The subject-matter should be of value not only to surgeons, but also to all who have to care for and advise patients.

The work is not written for the expert, though we believe it contains contributions which he cannot afford to ignore: nor is it meant for the undergraduate student, though many of the articles, written with the simplicity which none but masters can achieve, will not prove too difficult even for the beginner.

The operations described and illustrated are those which our contributors have proved by experience to be sound according to present-day standards; we have excluded those, of whatever repute, which are no longer regularly employed.

As General Editors we must accept responsibility for what appears in these volumes, but we have taken the view that having chosen our man, we should allow him to express his preferences without undue interference. Full agreement over details is scarcely to be expected, but the work as it stands is a reliable guide to sound practice.

E. Rock Carling.
August 1947. J. Paterson Ross.

ABDOMINAL EMERGENCIES

By JOHN MORLEY, Ch.M., F.R.C.S.
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1. DEFINITION

1.] In considering the principles relied upon in the diagnosis and treatment of patients who present an acute emergency of spontaneous or non-traumatic origin, it is the surgeon's task to determine accurately the precise nature of the abdominal catastrophe, so that he may form a sound judgment whether operative or other treatment is demanded.

General considerati[ons]

2. DIAGNOSIS

It is well to approach the problem by stressing the two conditions which may most often simulate a true abdominal lesion. These are the gastric crises of tabes dorsalis, and basal pleurisy.

(1) Gastric crises

The association of an attack of acute pain in the upper abdomen, so severe that only morphine will relieve it, with urgent vomiting, occurring in an

unrecognized tabetic, may lead to an erroneous diagnosis of peritonitis or acu intestinal obstruction. The absence of true involuntary rigidity of the abd minal muscles or of distension will arouse the suspicion of the discerning, bı the only safe rule is to make sure that the pupils react normally and that tł knee jerks are active in all cases of supposed abdominal emergency.

(2) Basal pleurisy

igns and ymptoms

An attack of pleurisy at the base of the right lung involving the outer part (the diaphragm gives rise to pain radiating down the lower dorsal nerves to th abdominal wall, combined with some degree of muscular rigidity in the rigl abdomen. These manifestations, with a raised temperature, may simulate a attack of acute appendicitis or acute obstructive cholecystitis. The relativel rapid shallow respirations with abnormal working of the alae nasi shoul arouse suspicion, and on auscultation a friction rub at the base of the lun will be heard. An associated shoulder-tip pain from stimulation of the centrε portion of the diaphragm supplied by the phrenic nerve is more in favour o pleurisy than of either appendicitis or cholecystitis.

eferred pain

(3) Complaint and symptoms

ype of pain

It is of importance to study the patient's pain. After elimination of thes extra-abdominal causes of the symptoms it is well to consider whether th trouble is inflammatory or obstructive, or due to a combination of these tw factors. This decision depends mainly upon the patient's own account of th pain, with special attention to its mode of onset, distribution and intensity and to its continuity or intermittent character, and on the presence or absenc of associated tenderness on palpation and muscular rigidity.

(4) Inflammatory intraperitoneal conditions

Visceral nsensitivity

It is fundamental to a correct assessment of the signs and symptoms that one should realize that the intraperitoneal viscera are themselves insensitive to the pressure of the palpating hand. One talks of a "tender" inflamed appendix or gall-bladder, although in fact such organs, when exposed under local anaesthesia limited to the abdominal wall, are insensitive. The inflammation makes no difference in this respect. The tenderness on pressure which we find over an inflamed appendix or gall-bladder, as well as the associated muscular rigidity, is due to stimulation by the inflamed organ of the adjacent parietal peritoneum (including in that term the sensitive peritoneum in the deeper portions of the mesentery). The exquisite sensitivity of the parietal peritoneum can only be compared with that of the cornea or conjunctiva. Anyone who has inadvertently squirted lemon juice or soap and water into his eye realizes the pain and reflex spasm of the orbicularis palpebrarum that result. Similarly, any chemical insult to the parietal peritoneum causes pain, tenderness and reflex muscular rigidity in the overlying abdominal wall.

Peritoneal irritability

(5) Perforated peptic ulcer

Peritoneal irritation is seen in its most dramatic form in acute perforation of a gastric or duodenal ulcer. Not only does the flooding of the sensitive parietal peritoneum with acid gastric contents give rise to a pain of intolerable severity and to a board-like rigidity of the whole abdominal wall such as is seen in no other condition, but the suddenness of the onset of the pain is characteristic. Not in any other abdominal emergency can the patient state

Onset of pain

with such unfailing precision the exact time of onset of the pain. This is a point of no small importance in deciding the diagnosis. Another characteristic feature is the shoulder-tip pain, which results when the acid gastric contents reach the under surface of the diaphragm. It is, however, less severe than the abdominal pain usually, and special enquiry must be made whether it is present.

Auscultation

Auscultation is of value since it reveals a death-like silence in the abdomen in place of the normal tinkling and gurgling of the small intestines during peristalsis. This intestinal immobility is another reflex mediated by the sensory nerves of the parietal peritoneum, whereby total inhibition of intestinal movement is secured through stimulation of the splanchnic sympathetic nerves. Thus harmful diffusion of septic material in the peritoneal cavity is reduced to a minimum.

Peristalsis inhibited

Pulse rate and quality

The pulse in the early hours after perforation is decidedly slow and full, in surprising contrast to the anxious, drawn expression of the face. Later, if an operation is not performed, the pulse rate rises steadily as peritonitis becomes well established, until finally we find the rapid, thready pulse, cyanosis and cold sweat that signify failing circulation and impending death.

Course

Occasionally a perforating ulcer leaks a little into the peritoneum and then becomes sealed by plastic lymph or adherent omentum. In such cases a small quantity of gastric contents may gravitate to the right iliac fossa and there give rise to local pain, tenderness and rigidity simulating acute appendicitis.

In neglected cases with advanced peritonitis and paralysis of the intestines the picture changes from one of great pain and rigidity to comparative comfort, with a tense distended abdomen and all the signs of failing circulation. In a case seen for the first time at this stage it may not be easy to determine, apart from the history of onset, whether one is dealing with the late stages of peritonitis or of intestinal obstruction.

(a) Prognosis

Early operation imperative

The prognosis of perforated gastric or duodenal ulcer depends upon early operation. In few conditions is the time factor so important. It may be said broadly that of cases operated on in the first twelve hours the great majority recover; in the second twelve hours about 50 per cent will survive, and after twenty-four hours the majority will die.

(b) Pre-operative management

In the early hours after the perforation the patient's circulation will usually be good, and operation should be carried out at once. It is only in the late cases with a rapid pulse and failing blood-pressure that some delay is imperative in order to make the patient a reasonably safe surgical risk. Two or three hours spent in administering normal saline or plasma by the intravenous route will be time well spent.

Transfusion in late cases

(c) Anaesthetic

Spinal

Spinal anaesthesia has the great advantage of securing complete relaxation. This enables the surgeon to carry out his operation with greater expedition and less trauma to the patient's tissues than under any other anaesthesia. It is only in the late and desperate case with a low blood-pressure that spinal anaesthesia is unsafe.

(d) Operative technique

ationale The object is to close the perforation and clean out the peritoneal cavity as quickly as possible. It is seldom advisable to attempt more ambitious procedures. Some surgeons have advocated a gastro-enterostomy, or even a subtotal gastrectomy in early cases, but it is wiser to save the patient's life by the simplest possible means, and to leave any complicated procedure that may prove necessary later to be done at a subsequent operation when there is no *echnique* early peritonitis to prejudice the result. The abdomen is opened by a right paramedian incision as high as possible. Free fluid in the peritoneum is sucked out if a sucker is available, but if not is gently sponged out with a series of gauze packs wrung out of warm normal saline. The perforation is then closed by one or two stitches of No. 0 catgut passed on a round-bodied curved needle through the whole thickness of the wall on each side of the perforation, and is oversewn by a continuous catgut sero-muscular suture, inserted at right angles to the long axis of the stomach or duodenum, so as to avoid stenosis. In some cases the tissues surrounding the perforation are so necrotic and friable that the stitches cut out. It may be then necessary to plug the hole by suturing a tuft of omentum into it. After cleansing the peritoneum carefully and gently of all the remaining gastric contents, the abdomen is closed without drainage. The custom of leaving in a suprapubic drain has little to recommend it and may cause a band of adhesions and later intestinal obstruction.

(6) Acute obstructive cholecystitis

The ordinary attack of biliary colic that signals the passage of a stone down the cystic and common ducts into the duodenum is easily recognized. It is appropriately treated by a dose of morphine, and when the patient awakes from the sleep thus induced the attack is usually over, and all that remains is slight local tenderness over the gall-bladder and transient jaundice for a day or so.

Complications A more serious and very common complication of gall-stones arises when a large stone becomes impacted in the neck of the gall-bladder at Hartmann's pouch, or a small one in the narrow cystic duct. In both cases the result is the same, an acute obstructive inflammation of the gall-bladder.

(a) Pathology

Organisms, chiefly streptococci, already present in the gall-bladder and its *Course of infection* wall, multiply extremely rapidly. Muco-pus is poured out into the gall-bladder, inflammatory oedema causes its wall to swell and there is increasing tension in the viscus, which swells rapidly. After three or four days the tension may be so extreme that the mucosa ulcerates and patches of gangrene may appear at the fundus. Unless the surgeon intervenes, perforation of the gall-bladder is then inevitable. The purulent contents may then escape into the general peritoneal cavity, setting up an acute general peritonitis, or omental adhesions may localize the mischief, when a subhepatic abscess results. More often, without ending so disastrously, after two or three days the inflammation gradually subsides. If the impacted stone then falls back into the gall-bladder more or less complete resolution follows; but if it remains impacted, the contents of the gall-bladder may become slowly sterilized and the empyema is then converted into a mucocele of the gall-bladder.

(b) Clinical picture

Symptoms and signs

The attack begins as in an ordinary attack of biliary colic with severe pain in the epigastrium, shifting later to the right hypochondrium and going through to the angle of the right scapula, but instead of being limited to a few hours it goes on for days, with a rising temperature, a foul and dry tongue and persistent pain. Tenderness and rigidity increase with the rapidly swelling, inflamed gall-bladder, and are most marked over the fundus (Fig. 1). In a severe case, where the fundus of the gall-bladder extends down to the right iliac fossa, a picture very like that of perforated appendicitis may be found. Rigidity of the abdominal muscles over the inflamed gall-bladder is so marked in the early days that it is often impossible to palpate the distended organ. Later, if the inflammation begins to subside, a large pear-shaped swelling may be felt. Jaundice is usually absent because the common duct is not obstructed. In some cases, however, there may be so much oedema round a large stone impacted in Hartmann's pouch that some compression of the hepatic duct is caused and slight jaundice results. Owing to the reflex inhibition of intestinal movements there is constipation and considerable distension, most marked in the colon.

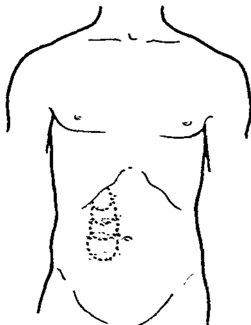


FIG. 1.—Shaded areas show downward movement of maximal tenderness and rigidity in acute obstructive cholecystitis with progressive enlargement of gall-bladder.

(c) Prognosis

Most attacks of obstructive cholecystitis settle down on expectant treatment, to be renewed some weeks or months later. It is, however, a difficult and anxious task to decide which are the cases that threaten to go on to gangrene, for these demand urgent operative measures.

(d) Indications for surgical intervention

In a small proportion of cases treated by rest in bed, sedatives, a light fluid diet and chemotherapy, there is no improvement after two or three days. The temperature remains elevated, the pulse rate is mounting a little, the tongue remaining dry and pain is not abating. There may even be rigors. The tenderness and rigidity are found to extend a little lower in the abdomen each day. In such circumstances gangrene and perforation of the gall-bladder are threatened, and unless the patient is for some other reason a desperate risk, it is better to undertake operation.

(e) Operative technique

Either spinal or general anaesthesia may be used, and the incision may be a vertical one splitting the rectus muscle, a transverse one or Kocher's incision

(*d*) *Operative technique*

Rationale

The object is to close the perforation and clean out the peritoneal cavity as quickly as possible. It is seldom advisable to attempt more ambitious procedures. Some surgeons have advocated a gastro-enterostomy, or even a subtotal gastrectomy in early cases, but it is wiser to save the patient's life by the simplest possible means, and to leave any complicated procedure that may prove necessary later to be done at a subsequent operation when there is no early peritonitis to prejudice the result.

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best opinion now favours non-operative treatment in severe cases when the diagnosis is fairly certain. Intravenous normal saline or plasma (but not glucose) is given in liberal amounts in an effort to support the failing circulation. Soluble Sulphamezathine should be given with the saline, or penicillin intramuscularly. If an abscess forms later, as evidenced by a palpable mass and a rising leucocytosis, it is drained. It is only in the less typical cases, where doubt arises whether there may be a perforated peptic ulcer or a high intestinal obstruction, that laparotomy should be performed, and the discovery of patches of fat necrosis and blood-stained peritoneal fluid with a swollen pancreas should lead the surgeon to close the wound at once although a tube may be left down to the pancreas for a few days.

(8) Perforation of the intestinal tract

Invasion of the peritoneal cavity by highly septic intestinal contents may occur below the duodenum from perforation of the following types:

Causes

(a) A swallowed fish bone, meat bone or other sharp foreign body penetrating the wall of the gut.

(b) A Meckel's diverticulum undergoing gangrenous inflammation and perforation.

(c) Perforation of tuberculous or typhoid ulcers of the small intestine.

(d) Gangrenous appendicitis with perforation.

(e) Acute perforative diverticulitis of the colon.

(f) Perforation of the colon above a stenosing carcinoma.

Differential diagnosis

Since appendicitis is so much commoner than any of the other causes of perforation, it is perhaps inevitable that the rarer forms should commonly be mistaken for perforative appendicitis. It is the most distinctive feature of acute appendicitis, however, that the attack is ushered in by a dull, heavy, ill-defined pain in or a little above the umbilical zone. In the early hours of the attack this pain is not associated with tenderness or rigidity on palpation. It is only after several hours, when a localized pain of a sharper quality appears in the right iliac fossa, that we find the characteristic tenderness and rigidity which make the diagnosis possible. In the rarer intestinal perforations, except those due to colon carcinoma, there is no such prodromal central pain, but the first symptom is the stabbing pain of peritoneal invasion. In such cases one must first attempt to guess what may be the source of the peritonitis by a careful consideration of the history and the localizing signs, and secondly whether that peritonitis is a diffuse and fulminating form demanding immediate surgical intervention or is becoming so localized by peritoneal adhesions that an expectant policy is justified.

(9) Tubal and ovarian lesions

(*a*) *Acute salpingitis*

Diagnosis

This is most commonly due to the gonococcus, is a common source of peritonitis in the lower abdomen, and is often confused with acute appendicitis. The pain is localized from the onset either to one iliac fossa or to both fossae, with no prodromal epigastric pain. There is pain on micturition from an associated urethritis, and leucorrhoea is present. On rectal examination of the cervix uteri marked tenderness is elicited. If a stained smear of the vaginal discharge shows gonococci, the diagnosis of salpingitis is fairly sure.

The treatment of acute salpingitis is essentially non-operative. Rest in bed in

parallel to the costal margin. The gall-bladder is exposed, adherent omentum is stripped gently off, and gauze pads wrung out of normal saline are placed round it. Some surgeons prefer to open and drain the gall-bladder, clearing out all stones at the same time, since they fear to remove the acutely inflamed and septic organ. This operation, however, leaves the greatly swollen walls swarming with streptococci, and does not relieve the patient of septic infection so surely as the bolder and better course of doing a cholecystectomy. The ducts must first be defined, the impacted stone identified, and the common duct examined carefully to see that it is free from stones. The cystic duct and artery are then gently dissected out and secured separately and divided between cholecystectomy forceps. This must be completed before the gall-bladder is stripped from the liver. If the gall-bladder is freed first, inspection of the ducts is hindered by a swamp of blood, and there is real danger of injuring the hepatic duct. When the gall-bladder has been removed, a hot swab packed into its bed for a few minutes checks the bleeding. The omentum is then packed into the gall-bladder fossa, a large-sized drainage tube is inserted for twenty-four hours and the wound closed.

Relative merits of cholecystostomy

Technique of cholecystectomy

(7) Acute pancreatitis

Surgical pathology

An inflammatory lesion that may often give rise to difficulty in diagnosis is acute haemorrhagic pancreatitis. The lesion may be regarded as in some sense obstructive as well as inflammatory, since gall-stones are present in some 70 per cent of cases, and may, by obstructing Vater's ampulla, bring about a retro-injection of infected bile into the pancreatic duct, with consequent escape of pancreatic juice into the tissue spaces of the gland. The necrosis and haemorrhagic inflammation thus caused give rise to great pain in the epigastrium, passing through to the back, and later diffusion over the whole abdomen whilst a blood-stained fluid exudes from the pancreas into the greater and lesser peritoneal sacs. The pain is of great severity and is often singularly resistant to morphine, but it lacks the dramatic suddenness of onset that one finds in perforated peptic ulcer; nor is there the same board-like rigidity. It is indeed characteristic of acute pancreatitis that the early rigidity and tenderness soon give place to distension of the upper abdomen. In a severe case the chief point in diagnosis is circulatory changes. The pulse is rapid and thready almost from the first, and one can detect a distinct cyanosis of the lips and tips of the ears. In less fulminating cases the symptoms are more equivocal and the condition may be confused with a severe acute obstructive cholecystitis. A rise of the urinary diastatic index is important diagnostic evidence of acute pancreatitis, and where laboratory facilities are available the urine should be examined for this in any doubtful case. The Löwi test, in which it is claimed that instillation of a few drops of a solution of adrenaline hydrochloride (Liquor Epinephrinae Hydrochloridi *U.S.P.* XII) 1 in 1,000 into the eye causes dilatation of the pupil, has proved quite unreliable in the diagnosis of acute pancreatitis.

Treatment

Although a diagnosis of acute pancreatitis is still regarded by some as an indication for immediate operation, it is questionable whether operation is justifiable. The severe toxaemia of the condition is due to absorption of toxins from the infected haemorrhagic slough in the substance of the pancreas, and the mere insertion of a drainage tube can hardly affect this absorption. The

common cause in Great Britain is rupture of a tubal pregnancy. In countries where malaria is endemic, rupture of the enlarged malarial spleen from comparatively trivial injury is common. Rarely an aneurysm of the splenic artery may rupture and bleed into the general peritoneal cavity.

Diagnosis

The diagnosis of intraperitoneal haemorrhage is not difficult, but patients are often sent to hospital with an erroneous diagnosis of perforated peptic ulcer. In the common ruptured ectopic pregnancy the following are the findings:

(a) The patient has recently gone a week or so beyond her normal time of menstruation and has some discharge of blood from the uterus.

(b) The attack is ushered in by an intermittent spasmodic pain in one iliac fossa and the sacral region, due to muscular spasm in the affected uterine tube.

(c) There is general abdominal pain, not of great severity, and some tenderness on palpation.

(d) In all severe intraperitoneal haemorrhages, shoulder-tip pain is felt in both shoulders.

(e) The abdomen is tumid, less exquisitely tender and less rigid than in perforative peritonitis, with shifting dullness in the flanks.

(f) The patient shows great pallor, a small thready pulse which comes and goes, restlessness and a tendency to faint and perhaps to vomit.

Operation should be performed as promptly as possible or the patient may bleed to death, but it is first essential to ascertain the blood group and set up an intravenous transfusion of blood by the drip method. The first pint may be run in rapidly, while the abdomen is being opened. A median incision is made below the umbilicus and the tubes exposed. The affected tube is excised and the bleeding controlled. The peritoneum is then evacuated of blood by suction or by gentle swabbing and the incision closed without drainage. Continuous blood transfusion is kept up until the patient's pulse rate and colour are restored to normal.

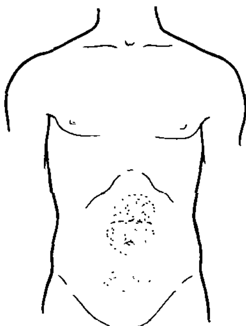


Fig. 2.—Usual sites in which true visceral pain in intestine is felt. Upper shaded area indicates site of duodenal and upper jejunal obstruction. Middle shaded area indicates lower small intestine obstruction. Lower shaded area indicates colon.

(12) Acute intestinal obstruction

Classical signs and symptoms

In the diagnosis of acute intestinal obstruction one relies on the symptoms of pain, vomiting and absolute constipation with distension. Pain is the most significant symptom. It is intermittent and colicky in type, and its position is a fairly accurate indication of the level of the obstruction (*see* Fig. 2). In simple obturation of the gut, as in obstruction of the

the Fowler position, and either full doses of sulphathiazole by mouth or a course of penicillin by continuous intramuscular drip will soon cause the inflammation to subside. It is only when there is a real doubt whether the condition is appendicitis or salpingitis that operation should be considered. If pus is found exuding from the uterine tubes the abdomen is closed without drainage and chemotherapy commenced.

(*b*) *Torsion of ovarian cyst*

Signs and symptoms

This condition causes acute pain in the corresponding iliac fossa and in the sacral region. The sacral pain is due to the drag on the broad ligament resulting from the torsion, and the anterior pain and tenderness are largely due to haemorrhage into the wall of the cyst which irritates the overlying peritoneum. The discovery on rectal or vaginal examination of a tense, fixed, rounded mass will usually make the diagnosis clear.

Treatment

The treatment consists in operative removal of the cyst.

(*c*) *Infected ovarian cyst*

Occasionally an ovarian cyst may become infected by blood-borne organisms and may rupture into the peritoneal cavity, producing a general peritonitis usually of a mild type.

Treatment

The treatment consists in removal of the cyst and cleansing the peritoneum of the escaped contents by suction or swabs.

(10) Pneumococcal peritonitis

Age incidence

In children between two and ten years of age, diffuse peritonitis caused by the pneumococcus is not uncommon. There are two distinct types.

(a) Primary, in which the sudden onset of diffuse peritonitis is the first event.

(b) Secondary, following or accompanying an attack of pneumonia.

The primary type is commoner and is confined to female children, since the pneumococcus nearly always gains access to the peritoneum via the uterus and uterine tubes. The onset is sudden with severe abdominal pain and vomiting, usually associated with some diarrhoea. The temperature is high (103° to 104° F.) and in the more fulminating cases there is early septicaemia with delirium and severe prostration resulting in early death unless energetic chemotherapy is initiated.

The differential diagnosis from appendicitis with peritonitis may be difficult. One relies chiefly on the absence of special tenderness or of a mass in the right iliac fossa, and on the temperature, which is seldom so high in acute appendicitis.

Laparotomy

It is wiser to explore the abdomen when there is any real doubt (as may often happen) whether the trouble is pneumococcal peritonitis or perforated appendicitis. If creamy odourless pus containing flakes of fibrin is found, with a normal appendix, the fluid is evacuated by suction and the abdomen drained for forty-eight hours, a specimen of the pus being sent for bacteriological examination. Energetic chemotherapy with sulphathiazole or penicillin is relied upon to combat the infection.

(11) Intraperitoneal haemorrhage

Traumatic lesions being excluded owing to considerations of space, we have only to consider spontaneous intraperitoneal haemorrhage. The only

and strangulated hernia are all common causes. In most cases, however, it is sufficient to diagnose acute obstruction, and it is essential to realize that every hour may count if gangrene of the gut is to be prevented.

(b) Pre-operative management

Although operation is urgent, a few hours must often be spent in making the patient safe for surgery.

Indications for transfusion

A small thready pulse, cold extremities and sunken features will show that the circulation is failing owing to the loss of water and chlorides from the blood. The blood volume must be restored by an intravenous drip of normal saline for two or three hours, before it is safe to operate. If there is copious vomiting and marked distension, a duodenal tube is passed through the nose or mouth and the contents of stomach and duodenum drawn off by continuous or intermittent suction. Many a patient with acute obstruction has been drowned in his own vomit during the operation owing to neglect of this simple precaution. Although one can avert the threat of dehydration by intravenous normal saline and gastric or duodenal suction, the danger of gangrene from strangulation demands the earliest possible operation.

(c) Operation

Spinal anaesthesia is preferable, unless the blood-pressure is too low. When the source of obstruction is obscure, a right paramedian incision is usually the best. The caecum is first examined. If it is distended, the obstruction is somewhere in the colon. If the caecum is empty and contracted, one follows the contracted ileum upwards until the site of obstruction is reached. Simple division of a band of adhesions may liberate a viable gut, or we may find a strangulated coil already gangrenous that requires resection and either end-to-end or side-to-side anastomosis. Where the small intestine is greatly distended, a Witzel enterostomy may be performed, or, before closing the abdomen, a Miller-Abbott tube (Fig. 128) passed down the oesophagus into the stomach may be manipulated through the pylorus well into the duodenum. Later, by inflating the balloon moderately, one stimulates the small intestine to drive the end of the tube downwards so that the distended gut can be decompressed by suction.

Procedure

Miller-Abbott tube

(d) Post-operative obstruction

Not uncommonly a few days after an operation for, as an example, perforative appendicitis, the patient complains of increasing distension, begins to vomit again and is unable to pass flatus. An enema fails to relieve the distension and the pulse rate increases. There is plainly a considerable degree of intestinal obstruction. Is this obstruction mechanical, due to kinking or to volvulus of an adherent coil of bowel, or is it paralytic (adynamic) ileus, due to a low-grade peritonitis which sets up reflex inhibition of intestinal movement? The answer is found in the character of the pain. If there are repeated spasms of colicky pain with loud peristaltic noises in the bowel, the cause is mechanical. If the pain is dull and continuous and on auscultation there is a deathly silence in the abdomen, the condition is paralytic ileus.

Causes

(e) Treatment

Purgatives or powerful stimulants to intestinal movement, such as preparations of physostigmine (eserine), acetylcholine or extract of posterior lobe of

ileum by a large gall-stone, or in strangulation of a knuckle of gut without the mesentery in a hernial sac, there are clear-cut spasms of central pain lasting approximately from half to two minutes, working up to an agonizing climax and then fading away rapidly. There is not any associated rigidity of the abdominal wall. Between these spasms are regular free intervals varying from five to fifteen minutes without any pain. When the deeper portion of the mesentery is strangulated along with the gut, pain is continuous between the spasms but there is the same relentless sequence of severe spasms during which the patient groans with pain. Vomiting is earlier and more urgent the higher the obstruction. In obstruction of the colon and lower ileum it may be greatly delayed. The vomit, at first reflex and consisting of stomach contents, is later composed of bile, then of small intestine contents with a malty smell, and finally becomes foul and stercoraceous. After the first urgent reflex vomiting the amount becomes more and more copious, and it wells up in effortless gulps of fluid. The bowels are constipated and no flatus is passed per rectum, although there may be much eructation of gas by the mouth. It was formerly the custom to give two test enemas to prove the presence of absolute constipation. The practice has been abandoned as possibly harmful and, in the presence of a Richter's hernia, misleading. Distension is present to a varying degree.

Type of pain

(*a*) *Examination of the patient*

(i) *Inspection.*—The form of the distension may indicate the level of the obstruction. If central it suggests obstruction of the small intestine. Obstruction of the colon causes bulging in one or both flanks according to its level. Visible peristalsis is not to be expected in really acute obstruction. It requires at least five days to develop, and before that time most patients with unrelieved acute obstruction will be dead. It is seen, however, in cases of chronic obstruction that have become acute, as in the "ladder pattern" in stricture of the lower small intestine or ileo-caecal valve, or above a stenosing carcinoma of the colon.

Site of distension

(ii) *Palpation.*—This may reveal an isolated tense coil of strangulated bowel, with some tenderness when it is greatly congested. The hernial orifices in the groin must always be palpated with great care, since a Richter's hernia in a femoral sac may give very little swelling at first and may be missed. Rectal examination must never be omitted.

(iii) *Percussion.*—This may reveal shifting dullness in the flanks showing the presence of free fluid in the peritoneum.

(iv) *Auscultation.*—It is important to distinguish mechanical obstruction, in which the peristaltic sounds from the small intestine are loudly exaggerated, from paralytic ileus, in which there are no peristaltic sounds at all.

(v) *Skiagram.*—A direct skiagram of the abdomen may reveal gas-filled coils of small intestine with fluid levels characteristic of small intestine obstruction.

(vi) *Causes.*—Recognizing the presence of acute obstruction is far more important than guessing its precise cause, which is often discovered only at operation. In infants under two years' old, acute intussusception is the commonest cause, and is easily recognized by the sausage-shaped tumour and the red-currant-jelly stool. In the aged, carcinoma of the colon, faecal impaction

ABDOMINAL PAIN

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1. DEFINITION

2.] Abdominal pain is defined as any deep pain felt within the anatomical boundaries of the abdomen. Although it most commonly arises from abnormal conditions of the abdominal viscera and peritoneum this is not invariably so; lesions of the chest, spine and abdominal wall are frequently its cause.

Deep and skin pain

The pain is always deep and diffuse with a characteristic aching quality. It is quite distinct from skin pain, which is always felt superficially, is accurately localized and has a typical burning quality.

Root pain

Mixed pain of both deep and skin types results from the stimulation of nerve trunks containing both skin and deep pain fibres. Such root pains are quite characteristic and will not be discussed in this chapter which deals only with deep pain and its associated reflexes.

2. INTRODUCTION

The manner in which diseases of apparently insensitive viscera cause pain, and the problems of abdominal pain in general, are difficult to solve, and are intimately associated with those of pain localization, referred pain and the reflex phenomena of muscle rigidity and skin tenderness.

Historical

In 1883 the idea of an irritable focus in the cord was introduced by Sturge and later elaborated by Ross (1888). Lennander (1903) showed conclusively that the viscera are relatively insensitive, and Mackenzie (1909), who was impressed by the insensitivity of the viscera, suggested that all visceral pain was due to non-painful impulses ascending from the viscera to the cord and spreading within it, so causing referred pain and reflex phenomena. There were, however, objections to this view, and Hurst (1911), Morley (1931) and others believed that painful impulses came direct from the viscera causing visceral pain while the reflex phenomena resulted from extension of the stimulus to the

pituitary (Pitressin), should not be used. The bowel should be decompressed by passing a Ryle's tube or, better, a Miller-Abbott tube into the stomach and endeavouring to coax it into the duodenum by turning the patient on his right side. Continuous or intermittent suction applied to the tube will relieve the distension. The patient may be allowed to drink while the tube is down, but fluid should also be supplied in the form of intravenous normal saline or plasma. If the obstruction is mechanical an operation will usually be necessary to free the adherent gut, but paralytic ileus can be treated most efficiently by continuous use of the Miller-Abbott tube for a few days in addition to chemotherapy and sedatives.

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[References to other titles are given under Abdominal Emergencies in the Index Volume. The subject of Abdominal Emergencies is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 1.]

In disease of the relatively insensitive visceral pain may be produced in three ways. First, by direct stimulation of adjacent sensitive structures such as the parietes or mesenteric roots. Secondly, by stimulation of a large mass of a viscus, and thirdly, by rendering the mesenteries hypersensitive through inflammatory or chemical changes so that pain is produced by the stresses and strain of visceral movement which do not normally produce any sensation.

Pain in disease

4. ANATOMICAL PATHWAYS

The sensitive viscera and the roots of the mesenteries are supplied with afferent nerve fibres which pass centrally through the splanchnic nerves and sympathetic ganglia to the posterior spinal roots. See Autonomic Nervous System —Anatomy, page 454, and Fig. 212.

Visceral

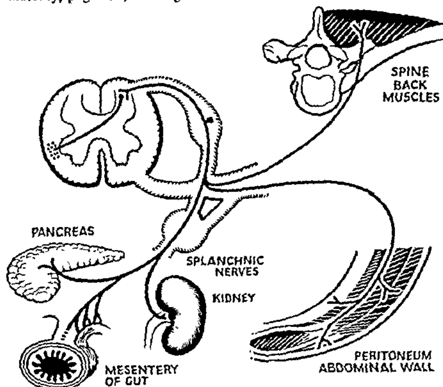


FIG. 3.—Afferent pathways of impulses causing abdominal pain. For simplicity all fibres following a common path are represented by a single line. Both somatic and visceral fibres have their cell stations in the posterior root ganglia. The second neurone crosses the cord and passes upwards in the spino-thalamic tract of the opposite side.

These do not differ in any way from the pain fibres supplying the deep somatic structures of the abdominal wall, the diaphragm and back, through the anterior and posterior divisions of the spinal nerves. They all have their stations in the posterior root ganglia whence they pass centrally through synapses across the cord and upwards in the spino-thalamic tracts (*see* Fig. 3).

Somatic

Although the segmental innervation of the somatic structures is well known, the segmental innervation of the viscera has not been fully worked out, and there appears to be some individual variation. For example, the stomach and duodenum may be supplied from the sixth to the ninth thoracic segments

Segmental innervation of viscera

surrounding parietes. Subjective observations on pain in diseased patients are not very satisfactory, and an experimental method was required.

Recent work

Using injections of 0·1 cubic centimetre of 6 per cent saline Lewis and Kellgren (1939) produced a pure severe pain comparable with that of disease. Such injections can be accurately placed in any structure and, since the observations can be repeated at will in subjects who are trained observers, much accurate information has been obtained about deep pain, its localization and referred distribution.

These experiments have shown that all structures deep to the skin give diffuse pain of a similar quality which is referred upon a common segmental pattern and accompanied by the same reflex phenomena, there being no distinction between pain arising from visceral or from somatic structures. The material for this chapter is largely drawn from these experimental results.

3. PAIN-SENSITIVE STRUCTURES

The structures deep to the skin vary greatly in their pain sensitivity and in their response to different stimuli.

Somatic

The subcutaneous fat is only slightly sensitive but deep to this is a very sensitive layer of deep fascia, periosteum and aponeurosis which gives severe pain with all forms of stimuli.

Skeletal muscle is relatively insensitive to pricking or cutting, but massive stimulation such as squeezing the muscle belly or stimulation by injection of hypertonic solutions or by ischaemia gives severe pain.

The periosteum, joints and ligaments are sensitive to all stimuli and may give rise to intense pain, but articular cartilage and compact bone are insensitive.

Serous membranes

The parietal peritoneum and pleura including both surfaces of the diaphragm are sensitive to all forms of stimuli, but there are areas on the posterior abdominal wall which are less sensitive, and the visceral peritoneum and pleura are completely insensitive.

Viscera

The viscera vary greatly in their sensitivity. The pancreas, bile ducts, renal pelves, ureters and bladder, the Fallopian tubes, ovaries and testes are sensitive to all stimuli.

The roots of the mesenteries are very sensitive but sensitivity diminishes as the gut is approached.

Solid organs

The solid organs such as the liver, spleen and kidneys are insensitive to cutting, burning or clamping, but pain may be produced occasionally by massive stimulation as when the whole organ is squeezed.

Hollow gut

The hollow organs of the alimentary tract such as the stomach, intestines, gall-bladder and rectum are insensitive to clamping, cutting or burning, but here again some pain may be produced by massive stimulation as in distension by a balloon. The uterus similarly may be cauterized painlessly, but dilatation of the cervix uteri may cause severe pain.

General

Most of the viscera are relatively insensitive, while the roots of the mesenteries are intensely sensitive. This is not surprising when it is realized that all nerve fibres from more than twenty feet of gut and from massive organs like the liver, spleen and kidneys are concentrated within a few inches at the roots of the mesenteries and around the pancreas.

From the sixth thoracic to the tenth thoracic roots the anterior component is large and the posterior component small, thus giving the pain its abdominal character; while from the twelfth thoracic to the second lumbar roots there is

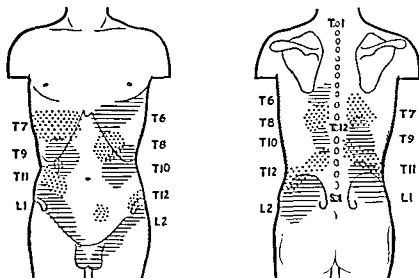


Fig. 4.—Shaded areas represent the distribution of deep pain and tenderness resulting from stimulation of the corresponding interspinous ligaments. Each segment has an anterior and posterior component, and there is much overlap.

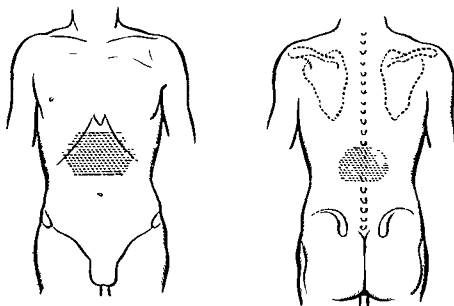


Fig. 5.—Shaded area represents deep pain and tenderness resulting from bilateral stimulation of the eighth thoracic interspinous ligament.

a larger posterior component which accounts for the backache of renal and pelvic diseases.

Bilateral pain tends to be placed in the midline (*see* Fig. 5).

bilaterally; the biliary tract from the seventh to the tenth thoracic segments mostly right side; the renal tract from the tenth thoracic to the second lumbar segments on each side. A fuller description would therefore be of little value until further detailed information is available.

5. PAIN LOCALIZATION AND REFERRED PAIN

Abdominal pain is rarely accurately localized but rather tends to be diffuse and frequently follows a segmental distribution and is then described as referred.

All the structures deep to the skin may originate pain which is more or less diffuse but may be localized with varying accuracy.

Local pain

The deep fascia, aponeurosis and periosteum covering the trunk gives pain which may be localized within one to three inches, and here a point stimulus gives local pain, although rarely centred accurately over the spot stimulated.

Segmental pain

As the stimulus is applied more deeply through the abdominal muscles and parietal peritoneum the pain becomes more diffuse and less accurately centred over the point stimulated. Finally the deep-lying structures surrounding the spine, thoracic cage and diaphragm give diffuse pain of segmental distribution which may be felt at some distance from the point stimulated.

The viscera and mesenteries also give diffuse pain of segmental distribution, but there is a tendency for the gut to give midline abdominal pain at the appropriate segmental level (Bloomfield and Polland, 1931).

Mechanism of reference

There is thus a gradual transition from local pain to the diffuse pain of segmental distribution.

The better-localized pain is obtained from the more superficial body structures of which we are conscious as a result of the daily experience of palpation and movement, whereas diffuse pain is obtained from the viscera and deep-lying somatic structures of which we are normally unconscious. This diffuse pain is projected to the region of those deep structures in which pain is well localized, and which are innervated by the same spinal segment which innervates the structure stimulated. In this way diffuse pain is given a segmental distribution by a process of faulty localization.

Pain complex visceral and somatic

Deep pain of both visceral and somatic origin has a similar quality. It is always more or less diffuse and is associated with referred deep tenderness, and certain reflex phenomena such as muscular rigidity and skin tenderness.

Symptom-complex

In this symptom-complex it is emphasized that the associated reflexes play no part in the mechanism of pain reference and that both visceral and somatic structures can give rise to the whole complex. There is therefore no single feature by which pain of visceral origin can be distinguished from somatic pain.

6. DISTRIBUTION OF PAIN

The segmental pattern followed by deep pain in the abdomen is as shown (*see* Fig. 4).

It will be noticed that this pattern differs from the segmental innervation of the skin, and that each segment has an anterior and posterior component which corresponds roughly in distribution with the areas in which the anterior and posterior spinal nerves pierce the deep fascia covering the trunk and give it a rich nerve supply.

side, although it always remains maximal in the region of the pain. Such rigidity can be produced by stimulating the sensitive abdominal viscera, the peritoneum and pleura and the spine and trunk muscles. Rigidity is therefore not peculiar to abdominal disturbances, but it is most intense when produced by stimulation of the parietal peritoneum or pleura.

The rigidity results from a spinal reflex and can be abolished by blocking the afferent or efferent pathways or by general anaesthesia.

(2) Visceral disturbances

Abdominal pain of whatever origin may be associated with visceral sensations and disturbances. Thus upper abdominal pain (seventh to tenth thoracic segments) is accompanied by a feeling of fullness or nausea and when severe by vomiting; whereas pain in the loin (twelfth thoracic to second lumbar segments) may cause frequency of micturition. Phenomena of this kind are many and varied. Their exact mechanism is not clearly understood, but for practical purposes it may be said that they are pronounced when pain itself is visceral in origin, and are much less evident when pain arises from the parietes or spine.

(3) Skin tenderness

Diffuse deep pain is sometimes associated with areas of hyperalgesia or sore skin. These areas often appear after the pain has ceased and may outlast it by many hours. Their distribution also differs from that of the deep pain in that it follows the segmental pattern of skin innervation, whereas the deep pain follows the pattern of segmental innervation of the deep structures. Skin tenderness thus differs from all the other associated phenomena which follow the spontaneous deep pain closely in time and distribution.

Skin tenderness is an irregular feature with marked individual variation. One subject will show intense widespread soreness with every pain, while another with similar pain will not show any at all.

Skin tenderness also spreads widely from local lesions of the skin itself, and may also result from the stimulation of nerve trunks through the action of antidromic impulses. It is therefore a complex and irregular phenomenon, and although frequently associated with visceral disease it is too unreliable to be of much value in diagnosis.

(4) Referred deep tenderness

Diffuse deep pain is always associated with tenderness of the deep structures within the distribution of the pain. This deep tenderness follows closely the spontaneous pain in time, intensity and distribution.

Within the distribution of the tenderness characteristic tender spots may be defined. These correspond with the structures normally most sensitive to pressure and are not of any special significance.

Referred deep tenderness is easily confused with the deep tender spot which represents the structure from which the pain arises. Referred tenderness is, however, rarely intense and always corresponds to the point of maximal spontaneous pain.

It will also be noticed that there is much overlap of the pain areas; for example, pain in the right iliac fossa may result from stimulation of any segment between the tenth thoracic and the first lumbar. The various structures which commonly give rise to such pain are shown (*see* Fig. 6).

From the diffuse nature of the pain and from the many structures which can give pain of a similar distribution, it is clear that this distribution is only a guide to its segmental level, and a very rough and even misleading guide to its source, for instance when pain felt in the abdomen has originated from the spine or chest.

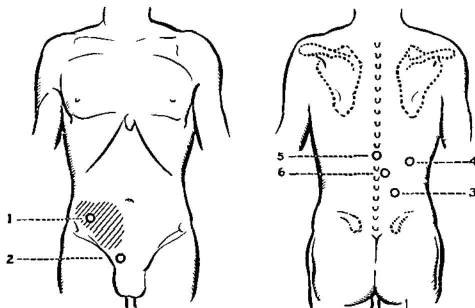


FIG. 6.—Hatched area shows common distribution of pain in right iliac fossa. Circles are over deep tender spots from which such pain may arise. (1) Ileo-caecal region, appendix and abdominal wall; (2) pelvic organs; (3) renal tract; (4) chest; (5) spine; (6) back muscles.

7. ASSOCIATED PHENOMENA

Diffuse deep pain in the trunk is accompanied by a symptom-complex which includes muscular rigidity, visceral disturbances, areas of skin tenderness and referred deep tenderness.

(1) Muscular rigidity

Severe deep pain is always associated with reflex tonic muscular contraction. In the abdomen this gives hardening and rigidity of the abdominal wall; in the chest, flattening and loss of movement; in the scrotum, retraction of the testicle. The rigidity follows the pain closely in intensity so that with intermittent colicky pain the abdominal wall can be felt to harden with each spasm of pain, and later to relax as the pain subsides. Continuous pain gives a continuous contraction.

The rigidity normally follows the distribution of the pain, but when pain is very severe it may spread to neighbouring segments and even to the opposite

muscle spasm and deep tenderness remain unchanged. If the deep structures are also anaesthetized, referred deep tenderness and muscle spasm are abolished but spontaneous pain remains. It should be remembered that the usual method of anaesthetizing skin by blocking cutaneous nerves with subcutaneous barriers of local anaesthetic also anaesthetizes wide areas of deep fascia and aponeurosis, so that this procedure reduces deep tenderness as well as abolishing skin tenderness.

If the deep tender spot, which is the source of pain, is anaesthetized the whole pain-symptom-complex including referred deep tenderness and muscle spasm is completely abolished, but skin tenderness may persist.

It is clear, therefore, that the results of local anaesthesia may be very confusing, particularly with subjects who are not trained observers. Local anaesthesia, however, may be invaluable in confirming a parietal source of pain such as a deep tender spot in the spine or back muscles, but it is reliable only when pain is severe at the time of investigation and when relief is complete and dramatic.

10. CLINICAL NOTES

Quality

All deep pain has the same quality so that nothing is to be gained by trying to distinguish between aching and cutting pains, or red-hot pokers or any other simile the patient may use.

Distribution

The distribution of pain is of less value than is generally supposed. The pain follows a segmental distribution and shows the segmental innervation of its source only. Thus pain in the right iliac fossa is often not appendicular in origin, and epigastric pain is not always caused by the stomach. However, midline pain posteriorly is spinal in origin, and midline pain anteriorly arises from the gut. Abdominal pain plus shoulder pain (third, fourth, fifth cervical nerves) means involvement of the diaphragm, and is clearly of great localizing value. Beyond this, little precise information is to be gained from the distribution.

Time-intensity curve

The time-intensity curve of pain is of great value. Thus colicky pain which waxes and wanes in a series of rhythmic waves is always visceral in origin, and comes from the hollow viscera and ducts. Pain which comes on with certain physiological acts such as micturition, defaecation and filling and emptying the stomach clearly comes from the affected viscus; in general, attacks of pain of great intensity and short duration are nearly always visceral in origin.

Chronic pain which remains constant for days is frequently somatic in origin and often comes from the spine, which conclusion is the more probable if pain is increased by movement or posture. Pain arising from the chest is usually intermediate, with increase on coughing and breathing as a prominent feature.

When visceral disease involves the parietes as in peritonitis, pleurisy, appendicular or perinephric abscess, somatic characteristics are added to the visceral ones, the pain being continuous and markedly increased by movement or coughing.

Visceral disturbance

Associated visceral disturbances such as vomiting, diarrhoea, cough or frequency of micturition usually indicate that the appropriate organ is involved, but severe pain from any cause may be accompanied by these disturbances. For instance, slight or moderate pain with vomiting is almost

8. DEEP TENDER SPOT

(1) General definition

The deep tender spot is the structure from which the whole pain-symptom-complex arises. Defining the deep tender spot is therefore the most important step in the diagnosis of pain. Once it has been accurately located we know what structure is causing the pain, and can proceed with the relevant investigations.

The deep tender spot must not be confused with the referred tender spots described previously. Pressure on the deep tender spot which is the source of pain causes both increase of spontaneous pain and referred tenderness, while it also increases rigidity and any visceral sensations that may be present. Pressure on the deep tender spot thus causes increase of the whole pain-symptom-complex. Increase of pressure also causes a steep increase of pain and if it be excessive the symptoms become unbearable, causing the patient to wince and cry out.

Pressure

Pressure on referred tender points gives only more pain than the corresponding points give normally, and increasing the pressure causes only moderate increase in pain, thus differing markedly from the deep tender spot. The points of referred tenderness are always found where maximal spontaneous pain is felt, whereas the deep tender spot frequently lies altogether outside the distribution of the pain.

(2) Clinical examples

Renal

In renal colic the referred tender spots are found in the back, the groin and the testicle following the distribution of pain, while the deep tender spot is in the renal pelvis. In peptic ulcer there is referred deep tenderness of the abdominal wall in the epigastric region, while the deep tender spot is at the site of the ulcer. In appendicitis the referred tenderness often overlies the deep tender spot making them difficult to separate, but the deep tender spot may sometimes be reached by a finger in the rectum and pressure here may then produce increase of pain, tenderness and rigidity in the abdomen, thus giving a clear demonstration of the deep tender spot. In peritonitis the deep tender spot lies in the peritoneum of the anterior abdominal wall, so that palpation reaches the deep tender spot at once, producing an immediate increase of pain, tenderness and muscle spasm.

Gastric

Appendicular

Peritonitis

Spine

In the spine a deep tender spot may lie between the spinous processes or around the small joints, in which cases it cannot be reached by the examining finger and can be demonstrated only by the exploring needle. When this strikes the spot there is sudden increase of abdominal pain and rigidity which is most striking, and it is in such cases that local anaesthesia is useful in confirming the situation of the deep tender spot.

9. EFFECT OF LOCAL ANAESTHESIA

Anaesthetizing an area to which pain is referred has given widely divergent results from different observers. This is largely due to failure to recognize the four separate phenomena: spontaneous pain, referred deep tenderness, muscle spasm and skin tenderness.

If the skin alone is anaesthetized, skin tenderness is abolished but pain,

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[References to other titles are given under Abdominal Pain in the Index Volume. The subject of Abdominal Pain is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 1.]

certainly abdominal in origin, while severe pain with vomiting may arise from the chest or spine.

Rigidity

Abdominal rigidity is often divided into guarding, which is thought to be a voluntary contraction to protect a painful viscus, and reflex rigidity due to peritonitis. This division is false in that all deep pain is associated with reflex muscular rigidity whatever its source, but when it is caused by disease of the spine, chest or abdominal viscera palpation at the site of rigidity does not increase its degree until the source of pain at the deep tender spot is reached with the palpating finger. In peritonitis the deep tender spot lies in the peritoneum directly under the palpating hand so that palpation produces an immediate increase of muscle spasm, and the greater the pressure the greater the spasm, thus producing the board-like rigidity of peritonitis. The rigidity of peritonitis is therefore clinically different from the reflex rigidity of all pain although the underlying mechanism is the same.

Deep tenderness

Defining the deep tender spot which represents the structure from which the pain arises is perhaps the most important step in diagnosis. In assessing tenderness, however, it should be constantly remembered that all deep pain is accompanied by referred deep tenderness within the distribution of the pain and that when the tender spot corresponds accurately with the site of maximal pain, the tenderness is probably of the referred type; but where the deep tender spot is at a distance from the pain, as when it is found by palpating the back or on rectal examination, then it is almost certainly the true source of pain. Frequently, however, the referred tenderness overlies the deep tender spot so that differentiation may be difficult. An important point is that pressure on the deep tender spot causes increase in the whole pain-symptom-complex including referred tenderness, muscle spasm and visceral sensations, while pressure on referred tender spots causes increase in pain only.

General

There is, of course, no simple method of determining the source of a given abdominal pain; all the features of the pain, its associated phenomena and related circumstances must be carefully considered and viewed in their proper perspective, and even then it is usually possible to make only a presumptive diagnosis which enables one to proceed with the appropriate pathological, radiological or other special investigations.

Personality

In every case the personality of the patient is of the utmost importance in assessing abdominal pain. A stimulus which in one subject will give only slight aching pain will in another cause the most intense pain with dramatic reflex rigidity and visceral disturbances. Apart from such differences in threshold there are also the more complex psychosomatic disturbances, and one must also decide what part the pain plays in the emotional and social make-up of the patient before arriving at a final conclusion as to its significance.

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supply; but those to the recti muscles run more or less transversely to the fibres of these muscles.

Results of nerve section

Incisions in the abdominal wall should not injure the nerve supply of any of its muscles. Injury to the nerves leads to muscular atrophy, muscular weakness and eventually to a post-operative hernia. Such a hernia, because of the

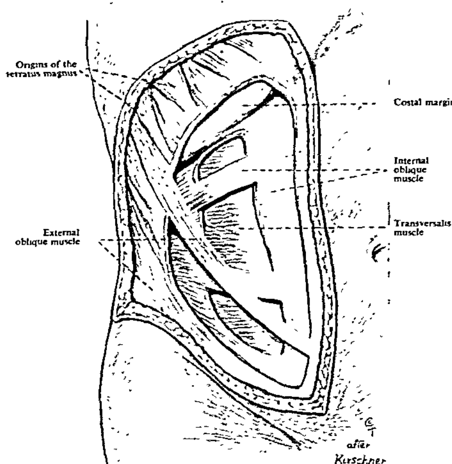


FIG. 7.—Musculature of the anterolateral abdominal wall showing the direction of the various flat muscles. (*After Kirschner.*)

absence of muscle tone, is practically irreparable. To bring about this condition more than one nerve must be injured. It is sometimes seen as the result of an unskilful execution of Battle's incision which is made along the lateral margin of the rectus muscle. With proper care the nerves entering the lateral margin of the muscle need not be injured.

(2) Disposition of the musculature

The disposition of the musculature in the abdominal wall varies. In the lateral regions of the abdominal wall the flat muscle layers are superimposed. In these regions the muscle fibres run transversely but in somewhat different directions. (*See* Fig. 7.) In the anterior regions the fibres of the recti muscles

ABDOMINAL WALL

By SIR HUGH DEVINE, M.S. (Melb.), F.R.A.C.S., Hon. F.R.C.S. Eng.

1. INTRODUCTION

3.] An abdominal incision should be designed so that when it has been faithfully repaired and has healed, no impairment of the efficiency of the abdominal wall should follow. It should also be so made and disposed that it gives such complete access to the operation area that the operation can be carried out in the best possible circumstances.

2. ANATOMICAL PRINCIPLES IN ABDOMINAL INCISIONS

To achieve the first objective involves a consideration of certain anatomical factors on which the strength of the abdominal wall depends. These include the nerve supply of the abdominal wall, the disposition of its musculature and of its postural tone, the distribution of its aponeuroses and to some extent the position of its blood supply.

(1) Nerves to the abdominal muscles

Supply and direction

These are derived from the lower six thoracic nerves and from the first lumbar nerve. The nerves of the lateral part of the abdominal wall run more or less in the same direction as the muscle fibres of the flat muscles which they

supply; but those to the recti muscles run more or less transversely to the fibres of these muscles.

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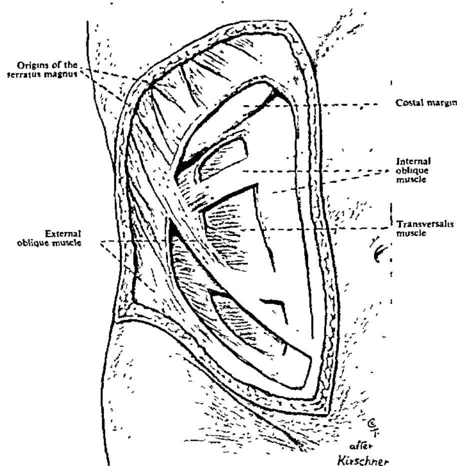


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run vertically. Lineae transversae in the muscle substance fuse the muscles with the anterior rectus sheath.

Direction of incision

It is an accepted principle that when making abdominal incisions the abdominal muscles should be *divided in a line parallel to their fibres, that is, in the* direction of their pull. If they are transversely divided their stumps retract and reunion is suturally difficult. Even if the stumps are satisfactorily apposed they subsequently tend to separate if there is any cause of delayed healing such as metabolic disturbances or wound infection of any degree. In this event a hernia which is difficult to repair is almost a certain sequel.

Lateral wall incisions

Thus *incisions made in the lateral parts of the abdominal wall present no* difficulty in conforming to anatomical principles. An incision which is placed transversely and runs in the same direction as the nerve fibres so as not to *injure them is also in the right direction so far as the muscle fibres are con*cerned, and the direction of the incision is in the direction of the muscle pull which causes the wound to close rather than to gape. Any incision, therefore, *in the lateral regions of the abdominal wall is made by separating the fibres,* in their direction, of the individual muscles. In this way a valvular incision is also made. This is one of the best, most used and safest of abdominal incisions. McBurney's incision is an example of this. In any part of the lateral region of the abdomen this principle can be used effectively. It is capable of being enlarged to a considerable size. (*See* Fig. 8.)

McBurney's incision

An apparent discrepancy

It is when we come to make incisions in the anterior and midpart of the abdominal wall—through the recti muscles—that there comes a clash in anatomical and incision principles. An incision which runs in the direction of the transversely running nerve fibres must cut across the vertically running rectus muscle fibres, and thus it must contravene *the principle that muscles should* be divided in the direction of their fibres.

Transverse division of rectus abdominis

There is, however, much to be said for *dividing transversely* that *part of the* rectus muscle which lies above the umbilicus. The transverse pull of the lateral muscles in the upper part of the abdomen is much stronger than that of the vertical muscles and this tends to make a vertical paramedian incision in the upper part of the rectus gape, but, as already *pointed out*, to make the edges of a transverse incision approximate. This strong lateral muscle pull is partly *the result* of a postural tone in the abdominal wall which is greatest in its central area and in its upper lateral parts. It corresponds to that part of the abdominal wall in which an extrapostural tone appears to be required to keep it tense and so to hold the intestines in their proper place in the upright position, that is, on that oblique shelf on the posterior abdominal wall just above the sacral promontory. In this area of postural tone it will be found that in vertical incisions the *suturing of the muscles and aponeurosis has often to*



Fig. 8.—*Split-muscle McBurney incision.* A. Sheath of rectus. B. Incision in C continued into sheath of rectus. C. Aponeurosis of internal oblique and transversalis.

be carried out under considerable tension. Thus, a transverse incision in the upper part of the abdomen which extends through the lateral wall and across the rectus—at a linea transversa—is not anatomically unsound.

In the upper part of the abdomen, these transversely running incisions are made because they give an excellent exposure of the whole of the upper part of the abdomen; they also have the advantage that they can be extended into the thorax to expose the lower part of the oesophagus. They are, however, as will be pointed out later, for the skilled surgeon, and for circumstances in which there is a faultless aseptic technique.

(3) Disposition of the abdominal wall aponeuroses

This comes into consideration when positioning an incision. There are parts of the abdominal wall in which there are no taut muscle fibres and through which the abdominal cavity is readily approached. Examples are the midline above the umbilicus and the aponeurosis lateral to the rectus muscle, the linea semilunaris. This approach through an aponeurosis has disadvantages; for instance, a midline incision above the umbilicus while giving good access cannot be closed in a valvular fashion because the recti muscles do not lie close together. (*See* Fig. 9.) The entirely aponeurotic scar is likely in time to bulge and form a hernia. Many surgeons use it habitually, however, and find that if the wound is carefully sutured and remains aseptic, healing is satisfactory.

3. THE VASCULAR SUPPLY

Anatomy of blood supply

This has a bearing upon the making of incisions. The superior epigastric artery, a branch of the internal mammary artery, descends in the upper part of the rectus sheath. The inferior epigastric artery arises from the external iliac artery about a quarter of an inch above the inguinal ligament and ascends towards the umbilicus. It crosses the outer border of the rectus two or three inches above its origin.

Technique

The superior epigastric artery must be avoided when making incisions for the removal of the gall-bladder, and the accidental injury of the inferior epigastric artery has led to serious subperitoneal haemorrhage in appendicular incisions or incisions through the lower part of the rectus muscle.

The deep circumflex iliac artery arises from the external iliac at about the same level as the inferior epigastric artery. It passes upwards and laterally along the inguinal ligament and the iliac crest. Immediately behind the anterior superior spine it gives a rather large branch which ascends between the internal oblique and transversus abdominis muscles. This branch may be injured when enlarging laterally an appendicular gridiron incision.

4. ADEQUATE ACCESS TO THE OPERATION AREA

(1) Objectives

After considering how to design an incision to avoid any permanent damage to the abdominal wall the second important objective is to obtain such access to the operation area that its anatomical structures are so adequately exposed, and the organs adjoining this area so disposed, that the operation can be effectively performed. The most important contributory factor is good anaesthesia.

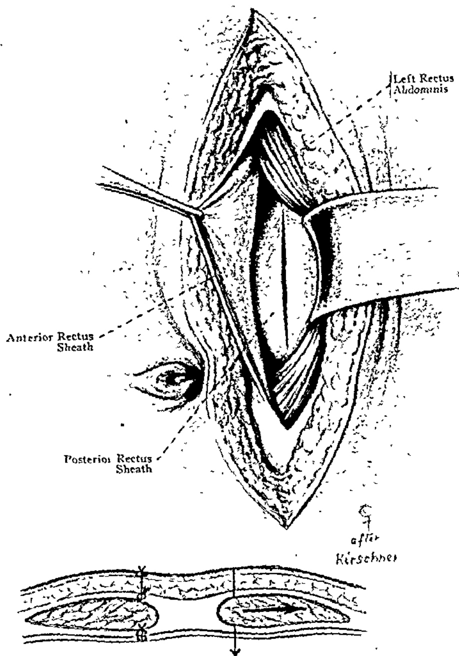


FIG. 9.—Paramedian rectus incision. The anterior sheath of the left rectus has been opened, the muscle has been retracted outward, and the posterior rectus sheath has been incised. The lower portion shows the diagrammatic cross-section through the central portion of the anterior abdominal wall, showing course and suture of the paramedian rectus incision. (*After Kirschner.*)

(2) The accuracy with which the incision can be placed over the lesion

Centre of incision

The centre of the incision should be over the most crucial part of the operation area, that is, over the part where the greatest difficulty will be encountered, and to attain this the surgeon must be able to localize the lesion. Skiagrams or clinical criteria may enable him to do this.

Gall-bladder and stomach

Incisions for operations on the gall-bladder or stomach should be placed as high and as near to the midline as possible, as these organs are tethered by their arterial supply. The cystic artery tethers the gall-bladder and the left gastric artery tethers the stomach. These arteries arise high in the epigastric angle close to the midline. Once these arteries are divided, the organs themselves can be almost bloodlessly separated from their peritoneal attachments and mobilized medially.

Adequate exposure

If incisions are to be placed as high as possible in order adequately to expose the vital part of the operation, no attempt should be made to extend the incision downwards (through the functionally important central part of the abdominal wall) to permit the removal of the appendix. The appendix should be localized by exploration from above. If non-adherent it should be removed through a tiny incision made directly over it. Multiple, small and accurately placed incisions yield better results and leave less damage than does the long paramedial incision through the central part of the abdominal wall.

Colon

Operations on the right or left part of the colon require a paramedian incision with its centre opposite the arterial supply: opposite the butt of the ileocolic artery in operations on the proximal colon, and the butt of the left colic artery in those on the distal colon. The bloodless lateral peritoneal colonic attachment is easily exposed—by proper retraction—and divided, and the colon with its mesentery brought to its arterial attachment—the midline.

Pelvic viscera

A subumbilical incision for exposure of the pelvic viscera should be median and should be as low as possible; it should extend between the pyramidales right on to the pubic bone because the vascular attachments are in the pelvis.

Appendix

For operations on the appendix the centre of the incision should be over the ileocolic junction because this is a fairly fixed point, and bears a definite relationship to the base of the appendix.

Spleen

For the spleen a left paramedian incision should be made with its centre opposite the vascular pedicle of this organ. The spleen can then be dislocated to this pedicle which lies close to the midline.

5. THE VARIOUS TYPES OF INCISION

(1) The split-muscle appendicular incision

Criteria for site

The position of the incision should be determined by the circumstances. Clinical evidence may suggest that the appendix is situated high, low or lateral. The incision should be placed accordingly. Usually the appendicular incision will be placed higher in children and lower in women.

Technique

The skin can be divided transversely in its natural line of cleavage, when an almost invisible scar will be obtained.

Gridiron incision

The external oblique, the internal oblique and transversalis muscles are split in the direction of their fibres to make a gridiron incision, and the parietal peritoneum is opened transversely. As a result of this incision the nerve

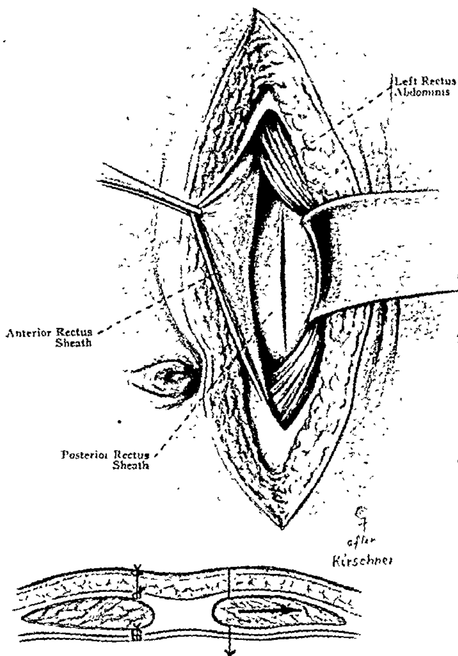


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Gridiron incision

supply, a twig from the ilio-inguinal nerve, to the internal oblique muscle may be injured. *For this reason an inguinal hernia is not infrequently seen following* an appendicular operation. Fig. 10 shows where this injury can occur. It will be avoided if the incision is not too low. In some cases the incision may need to be enlarged, and if so, the incision in the transversalis muscle and internal oblique aponeurosis is continued transversely into the rectus sheath. (*See* Fig. 8.)

Split-muscle incision

A split-muscle incision, as described above, can be used in any part of the lateral regions of the abdomen and will give excellent operative exposures, especially if used in conjunction with a properly balanced retraction. Sometimes it may be found that a split-muscle incision, made over the position of the normal appendix, will not completely expose a subhepatically placed inflamed appendix. In this case another split-muscle incision directly over the abnormally situated appendix is made. The first incision should not be extended because it will injure *transversely running muscle and nerve fibres.*

Twin incisions

Twin split-muscle incisions can also be advantageously used to *expose a very long normally based* inflamed appendix which has extended subhepatically.

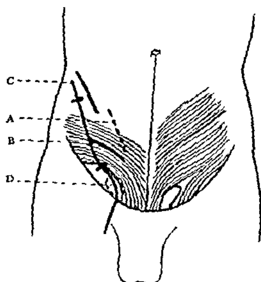


FIG. 10.—*Diagram to show how an inguinal* hernia occasionally follows an appendical *operation. In the appendical operation a* small branch of the ilio-inguinal nerve which supplies the *internal oblique is injured.* C. Ilio-inguinal nerve. A. appendicular incision. B. *Filament of the ilio-inguinal nerve supply*ing the internal oblique. D. External ring. The top cross bar shows where the nerve is usually injured.

(2) Incisions for cholecystectomy

Objective

Since cholecystectomy rather than cholecystotomy is the operation of *election, the objective in* placing the incision is to expose freely the critical part of the opera*tion area. This is the junction of* the cystic and common ducts, the trunk of the cystic artery, and the common duct in its whole length since its patency is so important *in a cholecystectomy. The dissec*tion of the cystic-common duct angle is a precaution against *accidents to the common* duct *when dividing* the cystic duct. The division of the butt of the cystic artery permits the mobilization of the gall-bladder medially with little bleeding.

(3) Rectus sheath incisions

Paramedian incision

The best incision *to expose this area* is a paramedian incision extending high into the epigastric angle and, when necessary, even extending across to the opposite side in order to ensure good exposure of the cystic duct area. (*See* Fig. 11.)

Technique

To provide an easy approach and a safe closure of the wound, the rectus muscle is split half an inch from its medial edge—the trans-rectal incision. (*See* Fig. 12.) The reason for this is that sutures cut out very readily from the transversely running fibres of the posterior rectus sheath unless a small section of rectus muscle with its longitudinal-running fibres is left. The subsequent atrophy of this small section of muscle which has been deprived of its nerve supply causes no permanent muscular weakness of the rectus muscle. (*See* Fig. 12.)

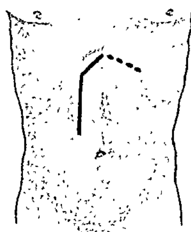


Fig. 11.—*Showing paramedian incision for* exposure of the gall-bladder, and how it can be extended to the other side if it is found that the stomach is also affected.

To get a perfect exposure of this operation area the small intestines must be "parked" away from the operation area into the adjoining parts of the abdominal cavity. The gall-bladder area, the junction of the cystic and the common duct, the common duct itself, the gastrohepatic omentum and the first and second parts of the duodenum (the crucial part of the operation area) are exposed and fixed, and stretched all ready for surgical intervention.

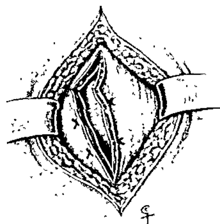


Fig. 12.—Showing perpendicular incision paramedially of the rectus muscle fibres so as to give a perpendicular grip to the sutures. The sutures show where a few vessels are tied.

Posture

Posture may be employed further to expose the area; the patient is placed in the reverse Trendelenburg position. In this position the liver and gall-bladder fall into a more manageable position; also the area can be better illuminated either by daylight or operation light.

Variation for gall-bladder exposure

A pararectal incision, in which the rectus muscle is displaced medially (Fig. 9), is frequently used to expose the gall-bladder. This incision does not afford the exposure as given by the paramedian incision described above. It is, in addition, tedious to make, it is difficult to extend to the left for a coexisting left-sided lesion and the transversely running

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The best incision to expose this area is a paramedian incision extending high into the epigastric angle and, when necessary, even extending across to the opposite side in order to ensure good exposure of the cystic duct area. (See Fig. 11.)

Technique

To provide an easy approach and a safe closure of the wound, the rectus muscle is split half an inch from its medial edge—the trans-*rectal incision. (See* Fig. 12.) The reason for this is that sutures cut out very readily from the transversely running fibres of the posterior rectus sheath unless a *small section of rectus muscle with* its longitudinal-running fibres is left. The subsequent atrophy of this small section of muscle which has been deprived of its nerve supply causes no permanent muscular weakness of the rectus muscle. *(See* Fig. 12.)

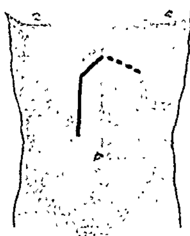


FIG. 11.—Showing paramedian incision for exposure of the gall-bladder, and how it can be extended to the other side if it is found that the stomach is also affected.

To get a perfect exposure of this operation area the small intestines *must be "parked" away from the* operation area into the adjoining parts of the abdominal cavity. The gall-bladder area, the junction of the cystic and the common duct, the common duct itself, the gastrohepatic omentum and the first and second parts of the duodenum (the crucial part of the operation area) are exposed and fixed, and stretched all ready for surgical intervention.

Posture

Posture may be employed further to expose the area; the patient is placed in the reverse Trendelenburg position. In this position the liver and gall-bladder fall into a more manageable position; also the *area can be better illuminated* either by daylight or operation light.



FIG. 12.—Showing perpendicular incision paramedially of the rectus muscle fibres so as to give a perpendicular grip to the sutures. The sutures show where a few vessels are tied.

Variation for gall-bladder exposure

A pararectal incision, in *which the rectus muscle* is displaced medially (Fig. 9), is frequently used to expose the gall-bladder. This incision does *not afford the exposure* as given by the paramedian incision described above. It is, in addition, tedious to make, it *is difficult to extend to the left* for a coexisting left-sided lesion and the transversely running

fibres in the rectus aponeurosis furnish little grip for catgut sutures which split in the direction of their fibres if there is much post-operative coughing or vomiting. Its valvular closure is its main advantage.

(4) Kocher incision

Technique

The Kocher incision is made parallel to and an inch below the costal margin. The rectus sheath and muscle are completely divided in this line, and the incision may be extended laterally through the oblique muscles. The seventh intercostal nerve may be spared if the incision is kept low enough; the eighth is usually sacrificed but the ninth should escape at the lateral end of the incision.

Advantages

The advantages of the Kocher incision are that it runs in the lines of cleavage of the skin and therefore leaves a fine scar; that post-operative pain is perhaps less than in the case of the paramedian incision; that the pull of the lateral abdominal muscles does not tend to make it gape, and that it gives direct access to the gall-bladder and to the cystic and common bile ducts. The disadvantages are that it does not lend itself to an extension of the incision for an operation on the stomach, and that a separate incision may be required to remove the appendix.

Disadvantages

(5) Incisions for operations on the stomach

General principles

Incisions to expose the stomach for surgical intervention are governed by the same principles as those for operations on the gall-bladder; the main vascular attachment, the left gastric artery, the division of which is the keypoint to the mobilization of the stomach, must be fully exposed. The stomach can easily be brought up from its peritoneal attachments to this vascular point, but it cannot be brought downwards to a lowly placed incision, designed perhaps to expose a lesion of the greater curvature, because of this vascular attachment which has then to be divided under disadvantageous conditions.

Technique

Thus, a paramedian incision, extending into the epigastric angle and towards the left side combined with the reverse Trendelenburg posture—to allow the stomach to drop—will give an exposure which is adequate for most gastric operations.

(6) Extension of upper paramedian incisions for a contralateral lesion

Technique

The incision for a gall-bladder operation must be capable of being so extended that it will permit an operation on the stomach, and the incision for a stomach should permit extension for an operation on the gall-bladder. This is effected in the following way: The right-sided paramedian incision (Fig. 11) is continued at its upper point through the upper part of the left rectus as it crosses the costal margin where the tone of the rectus is very poor and makes sutural closure easy. The posterior sheath of the rectus below the costal margin is then transversely divided, which permits a valvular closure, and the incision is continued for half an inch into the lateral muscles of the abdominal wall.

To carry out an operation on the gall-bladder when the incision has been made for a gastric lesion, the left-sided paramedian incision is extended to the right partly through the rectus muscle much in the same way as the right-sided paramedian incision is extended to the left side.

(7) Transverse incision across the upper part of the abdominal wall

Technique

A transverse incision (the idea came from Sprengel, 1910) through both sides of the upper part of the abdomen has, of latter years, come somewhat into use. It extends through both recti from one to two inches above the umbilicus and into the lateral musculature on both sides. It is designed to expose the upper part of the abdomen so that it will permit the performance of any operation in this region. It has been extended to the left end through the lower part of the thorax for operations in the region of the cardio-oesophageal junction.



Fig. 13.—Showing the medial edges of the rectus muscle lying close together in the lower part of the abdominal wall. A is the remnant of the urachus

(8) Incisions for lesions in the lower part of the abdominal cavity

Technique

A midline incision gives the best exposure of the lower part of the abdomen, and since the medial edges of the recti muscles in the lower part of the abdomen lie close together (Fig. 13), and there is no posterior layer or rectus sheath, they can be securely closed by suturing the muscles together and firmly supporting this by well overlapping the aponeurosis. Fig. 13 shows the closeness of the medial edges of the lower part of the recti muscles.

The incision should be continued between the pyramidales muscles to the pubic bone because the incision must extend as low as possible in order to ensure the best exposure of the pelvic viscera.

The incision should be made with the patient in the Trendelenburg position as this allows the intestines to fall away from the operation area, the light to be reflected into the cavity of the pelvis, and the pelvic viscera to fall into a better position for operation. Thus the full value of this incision is exploited by posture.



Fig. 14.—Transverse section of upper part of abdominal wall. A shows the space between the recti.

(9) The incisional-hernia-like method of closure

Closure of median incision

The use of this method is the vital point in the use of this median in preference to a paramedian incision. Often there is a post-operative weakness following a paramedian incision which is due to a pre-operative bulging—especially in women—caused by a divergence of the recti muscles which is not improved by a paramedian incision. The incisional-hernia-like way of closing a median incision in the lower part of the abdomen prevents or cures this post-operative bulging (Fig. 15). The keel-like closure (Fig. 16) also gives a firm abdominal wall where the aponeurosis is loose.



FIG. 15.—Imbrication method of closing median incision in the lower part of the abdomen. This prevents bulging of the wound, especially in slack abdomens.

The median incision gives the best exposure, lends itself to a strong muscle-aponeurotic closure, can be used, with little additional trouble, to build up the strength of a weak lower abdominal wall and permits a more exact care of the urinary bladder.

(10) Incisions through an old operation scar

For reasons which need not be discussed here it is often necessary to enter the abdominal cavity through the scar of a previous incision. In this case the abdominal cavity should be entered by a small incision through normal tissues, either at the upper or the lower end of the old incision.

6. THE CLOSURE OF ABDOMINAL INCISIONS

(1) Technique

A soft, filmy and wet scarf is packed into the wound and a spoon laid over this. (*See* Fig. 17.)

Kelly's needle

In order to leave very small holes and thus minimize the formation of post-operative adhesions the peritoneum is sutured with a fine round small atraumatic Kelly's needle.

The peritoneal edges are everted by the method of suture shown in Fig. 16. The suture should be drawn tight only during the expiratory phase of respiration when the abdominal wall is relaxed; if tightened during the inspiratory phase the suture is liable to cut out of the peritoneum.

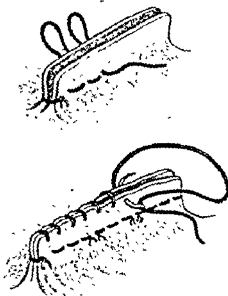


FIG. 16.—The keel method of closing the loose aponeurosis in a median lower abdominal incision. The apposing aponeurosis is made into a deep keel.

Procedures to aid closure

Should the abdominal muscles be tense, as they may be in parts of the incision which abut on the central and middle parts of the abdominal wall where the postural tone is high and where, as a result of this tension, it is difficult to bring the peritoneal edges together, the following manoeuvres can be adopted:

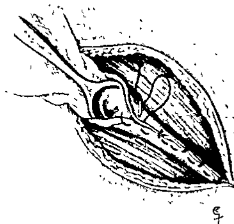


FIG. 17.—Showing the closure of the peritoneum.

(1) A running peritoneal suture is inserted for an inch or more but not drawn tight; mattress sutures are inserted far out from the cut edge of the aponeurosis, drawn tight and knotted; these sutures take the tension off the running peritoneal suture which can then be easily tightened and locked.

(2) The patient can be placed in the reverse Trendelenburg position which relaxes the postural tone.

(3) The peritoneal suture is only drawn tight at the end of each respiration.

Closure of wound

The muscle and aponeurotic layers can be closed in many ways. A good routine method is to bring the aponeurotic flaps together by a running mattress suture passing through each of the flaps about half an inch from their edges and interrupt it by an overstitch about every three-quarters of an inch. (*See* Fig. 16.) This is done to make a wide area of aponeurotic union and to bring the edges of the muscle close together.

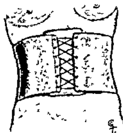


FIG 18.—A belt to be used to stay an abdominal wall.

It is a very good practice to imbricate the aponeurosis either by running sutures as in Fig. 16 or by using interrupted sutures, and this method is a great insurance against post-operative disruption of a wound.

Reinforced silkworm-gut sutures are not introduced through the muscle fibres but only through the aponeurosis.

(2) Precautions in regard to the removal of sutures

Impaired healing power

In patients suffering from debilitating diseases in which their tissue vitality is greatly impaired, post-operative disruption of the wound is likely to occur. To

guard against this, special precautions must be taken not only in the choice of sutures used to close the abdominal wound, but also in the time when non-absorbable sutures of the silkworm-gut type should be removed.

Some of the conditions which cause such a lowering of tissue resistance are late cancer, diseases of the liver and pancreas (especially those with jaundice), tuberculous conditions, late ulcerative colitis, general infection, general emaciation, agranulocytosis and some blood diseases. In these, a more insoluble catgut (slightly chromicized gut) should be used. Aponeurotic flaps should be widely imbricated with interrupted sutures. More silkworm-gut stay sutures should be inserted and these should be left in longer than usual, say for fourteen days. Post-operative coughing or vomiting should be minimized as far as possible, and the patient's abdomen should be encased in a laced rubber corset. (*See* Fig. 18.)

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[References to other titles are given under Abdominal Wall in the Index Volume.]

ABORTION

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1. DEFINITION

4.] Abortion is defined as expulsion of the products of conception from the uterine cavity before the foetus becomes viable, that is, before the twenty-eighth week of pregnancy; the terms abortion and miscarriage are synonymous. Abortion usually occurs before the fourteenth week of pregnancy.

Incidence

The incidence of abortion has been variously estimated as between one in every four and one in every seven births.

2. AETIOLOGY

(1) Spontaneous abortion

(a) Maternal causes

Causes affecting the general health of the mother include such evident factors as acute febrile illness and severe shock or fright. Less certain factors are endocrine abnormalities of the corpus luteum or of the anterior lobe of the hypophysis. The part played by the rhesus factor in habitual abortion is as yet uncertain.

Local causes include fibromyomata, retroversion and deep cervical lacerations.

(b) Foetal causes

Foetal causes include death or malformation of the foetus and low implantation of the ovum.

(c) Paternal cause

Abnormality or defect of the sperm may be responsible for some abortions.

(2) Criminal abortion

The patient may attempt induction of abortion by taking drugs such as lead compounds, ergot, quinine or *Mentha pulegium* (pennyroyal), although these are seldom effective even in toxic doses. The passage of uterine sounds or of knitting needles, the employment of abortifacient agents such as sticks of the bark of *Ulmus fulva* (slippery elm) or douching with a whirling spray are other methods adopted. *Injuries* In unskilled hands these may result in injury to the rectum, the recto-uterine pouch or the bladder. Lack of aseptic precautions entails grave risk of infection.

3. CLINICAL TYPES OF ABORTION

All abortions are brought about by haemorrhage into the chorio-decidual space. This bleeding is either preceded or followed by uterine contractions. The various types are but stages in the same process.

(1) Threatened abortion

Physical signs

The term, threatened abortion, is applied to a condition in which, in the early weeks of pregnancy, there is bleeding from the uterus without regular uterine contractions. There is no dilatation of the internal os of the uterus. As long as the internal os is closed, the bleeding, although quite severe, may cease and the pregnancy may proceed to term. There is no evidence that foetal abnormality ensues after threatened abortion.

(2) Inevitable abortion

This term is used when there is no hope of saving the pregnancy. There is dilatation of the internal os through which the developing ovum can be felt by the examining finger, but the bleeding and uterine contractions are more severe. *Pyrexia* During the progress of an inevitable abortion, fever, with temperature up to 102° F., may occur; since the fever is aseptic in origin, the temperature falls to normal after expulsion of the ovum.

(3) Incomplete abortion

The term incomplete implies that some of the products of conception, usually the whole or part of the placenta, are retained in the uterus. Until these products are removed the uterus remains bulky, the cervical canal is dilated and the bleeding persists. *Cervical abortion* A cervical abortion is a variation of incomplete abortion, the ovum being retained in the dilated cervical canal. Severe pain may accompany the condition.

(4) Complete abortion

Complete abortion implies spontaneous expulsion of the ovum and membranes. The cervix closes and the bleeding ceases once the uterus is empty.

(5) Missed abortion (carneous mole)

With missed abortion there is intra-uterine death of the ovum and retention of the ovum and clot in the uterus. The history is generally one of threatened abortion in the early weeks of pregnancy, the death of the ovum not being detected at the time. Subsequently, symptoms of pregnancy such as vomiting and breast changes subside. Examination some weeks later shows that the uterus has not enlarged; in fact it may even be smaller and harder than it was at the time of the threatened abortion. A brown discharge or repeated small haemorrhages may occur.

Symptoms

Physical signs

4. SPECIAL AIDS TO DIAGNOSIS

Most cases of abortion present few difficulties in diagnosis but it is sometimes necessary to establish a diagnosis of pregnancy in its early weeks. The Aschheim-Zondek or the Friedman test, in which a first morning specimen of urine is used, is helpful, although a negative report cannot be relied upon until three weeks after the patient's first "missed period". In the case of a carneous mole the test may remain positive for some weeks after the death of the ovum.

Pregnancy tests

In doubtful cases of early abortion pathological examination of material passed or obtained by curettage will establish the diagnosis of abortion if chorionic villi are found.

Pathological investigation

5. DIFFERENTIAL DIAGNOSIS

(1) Threatened or complete abortion

With a closed cervix, threatened or complete abortion may be confused with endocrine haemorrhage. In the latter condition—for instance metropathia haemorrhagica, when a period of amenorrhoea is followed by uterine haemorrhage—the uterus is not enlarged, the Friedman test is negative, and no villi are to be found on examination of curettings.

Endocrine haemorrhage

Should an appendage swelling, such as a tender blood cyst of the ovary, coexist with an early abortion, the differential diagnosis from an ectopic pregnancy or tubal mole may be made only after a pathologist's findings of villi in the curettings. When there is an ectopic pregnancy the curettings will show decidual cells but no villi. An abortion usually is accompanied by much bleeding and little pain, whereas the reverse is the case with an ectopic pregnancy.

Ectopic pregnancy

(2) Inevitable or incomplete abortion

This type of abortion may be confused with conditions which lead to dilatation of the cervix and to partial extrusion of the mass from the uterus. The commonest cause of such a condition is a fibroid polypus; a less common cause is an endocervical carcinoma.

(3) Missed abortion (carneous mole)

Here the chief pitfall is the mistaking of a live ovum for a dead one. If any doubt exists, the patient should be re-examined in a month's time. A carneous mole can be confused with a fibromyoma of the uterus but the latter condition is seldom associated with amenorrhoea unless pregnancy coexists.

Fibroids

(4) Criminal abortion

Many accidents may follow attempts at procuring abortion. When the recto-uterine pouch is injured or the uterus is perforated, or when fluid is douched through the uterus and the Fallopian (uterine) tubes, the symptoms are referable to the peritoneal cavity and vary between peritonism and generalized peritonitis. Septicaemia, without evidence of local trauma, may ensue after attempts at criminal abortion.

Vaginal bleeding or evidence of local trauma may point to the pelvic source of infection. Owing to reticence on the part of patients who have procured a criminal abortion, it may be difficult to establish a diagnosis of pregnancy. A history of amenorrhoea or of morning sickness, together with examination of the breasts for signs of recent activity, may be helpful, although the origin of the peritonitis may be in doubt until—occasionally even after—the abdomen has been opened.

6. PROGNOSIS

The dangers of abortion are sepsis and haemorrhage. The former seldom is a result of spontaneous abortion, but is a common result of induced abortion, and varies from local uterine sepsis to septicaemia and peritonitis. Haemorrhage may be responsible for death, but this should rarely occur if skilled attention is available. In cases of criminal abortion the patient is apt to delay seeking help, and the delay may be fatal.

7. TREATMENT AND INDICATIONS FOR SURGICAL INTERFERENCE

(1) Threatened abortion

Expectant treatment

The treatment, immediate rest in bed, is entirely expectant. Morphine, ¼ grain, should be administered immediately, and 20 grains of potassium bromide three times a day; 5 milligrams of progestin (progesterone) should be given every six hours for the first twenty-four hours, and afterwards once daily until the bleeding stops; vitamin E capsules should be given twice daily. Diet should be light, and purgatives and enemas avoided. Glycerin suppositories are a useful alternative to the latter. The patient should rest in bed for one week after the bleeding stops. Advice to patients liable to miscarry should include avoidance of sexual intercourse or of violent exercise, with rest in bed at the time of the first three suppressed periods.

(2) Inevitable abortion

The indication is to empty the uterus. If the bleeding is not severe, and the cervix is well dilated intramuscular injection of 0·5 cubic centimetre of posterior pituitary extract followed by a simple enema may be tried; this often leads to expulsion of the ovum. Severe bleeding may be controlled temporarily by plugging the vagina with a gauze roll soaked in 5 per cent Dettol.

Plugging vagina

If opportunities for surgical procedure are available the uterus should be emptied by means of ovum or sponge forceps, after preliminary dilatation of the cervix, if necessary.

Curettage

A blunt flushing curette may be used gently to explore the uterus for fragments of placenta. A sharp curette should never be used.

(3) Incomplete abortion

This type of abortion is treated in the same way as is inevitable abortion. If the patient is seen some weeks after the original abortion, administration of ergometrine, 0·5 milligram twice daily, may be tried for a few days; if the bleeding does not stop a sharp curette may have to be used if a small piece of placenta is adherent to the uterus.

Sepsis chemotherapy

Sepsis occurring after incomplete abortion is treated on lines similar to those employed in puerperal sepsis. The organism should be identified, and treatment carried out with the appropriate sulphonamide when the organism responsible is known to respond to this form of therapy. A large dose given in the early stages and then discontinued is recommended—1–2 grammes, three times a day for the first three days; if the temperature persists after this time, the dose should be halved. The treatment should be discontinued altogether a week from the start, since, if the infection is not under control by then, it is unlikely that it will respond to further chemotherapy. Antibiotics such as penicillin, however, may be successful. Exploration of the uterus should be undertaken in septic cases only when haemorrhage is severe. For septic endometritis with purulent discharge use glycerin introduced into the uterus through a gum-elastic catheter which is left *in situ* for twenty-four hours.

Peritonitis

In cases of generalized peritonitis after criminal abortion the treatment is laparotomy and drainage, with conservation of the uterus. The outlook, however the condition is treated, is very grave.

(4) Missed abortion (carneous mole)

Although expulsion of the dead ovum may be spontaneous, once the diagnosis is established beyond doubt the uterus should be emptied without delay. Medical means should be tried first. Stilboestrol (5 milligrams three times daily by mouth) should be given for three days, followed by a medical induction with Pitocin (2 units hourly for six doses). If this treatment is unsuccessful the uterus should be emptied as in therapeutic abortion.

Medical induction

8. POST-OPERATIVE CARE

The patient should be kept in bed for one week after an uncomplicated abortion. Ergot should be given for the first few days. The patient should be examined before she is allowed to get up in order to make sure that the uterus is well involuted and in good position, with the cervix closed. If the breasts tend to fill with milk 5 milligrams of stilboestrol should be given twice a day from the second to the fifth day.

Where there is a history of abortion, the patient should be advised to return for ante-natal prophylactic treatment.

[References to other titles are given under Abortion in the Index Volume. The subject of Abortion is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 47.]

ABSCESS

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5.] In this article the stages leading to the formation of an acute abscess will be described in terms of general pathology. For the causes and specific characters of acute abscess in special situations reference should be made to the organ or tissue concerned.

1. DEFINITION

An acute abscess is the outcome of acute suppurative inflammation when this process is sharply localized in the depths of an organ or tissue by a cellular reaction zone of granulation-tissue which prevents the free diffusion of purulent exudate.

2. AETIOLOGY AND ROUTES OF INFECTION

Although an acute abscess can be produced experimentally in the total absence of bacteria by powerfully irritant chemicals like turpentine, it can be taken as axiomatic that all naturally occurring suppuration is due to bacterial infection. A large number of bacteria are capable of producing acute abscess. Many of these do so only when there is some exceptional alteration in the host-parasite relationship. The number of infecting micro-organisms may, for instance, be exceptionally large, or the general or specific resistance of the patient, or of the affected tissue itself, may be low.

Acute suppurative inflammation, on the other hand, is the specific tissue response to infection by many virulent strains of the Gram-positive pyogenic cocci and it can be taken to be the usual and characteristic response to infection by the coagulase-positive staphylococci (*Staphylococcus pyogenes*). Most but not all strains of staphylococci producing a golden-yellow pigment fall into this group which also includes some strains of *Staph. albus*. The majority of coagulase-positive staphylococci are haemolytic.

Infection by pyogenic cocci

Coagulase-positive staphylococci

In any particular case in which a micro-organism has given rise to the production of an acute abscess, *this fact alone is sufficient proof of its virulence to that individual whatever its* in vitro *bacteriological characters may eventually prove to be, and it must always be assumed that the micro-organism concerned is capable of producing acute suppurative inflammation with or without acute abscess formation in any of that patient's tissues or organs.*

Clinical proof of virulence

The following is a general summary of the common routes by which bacteria which have produced an acute abscess may have gained access to the affected tissue:

Routes of infection

(i) *By breach of surface*, traumatic or pathological, of the skin or a mucous membrane, including the open placental site.

(ii) *By extension into a duct or duct system* leading to a contaminated surface or opening into a contaminated or infected tube or hollow viscus, and often aided by duct obstruction with alteration and infection of retained secretion, e.g. staphylococcal abscess of dermis; lung abscess behind a stenosed bronchus; prostatic abscess, parotid abscess, breast abscess, pyosalpinx.

(iii) *By rupture of a tube or viscus* distended by infected inflammatory exudate or containing contaminated material, e.g. perforation of appendix and appendix abscess; pelvic abscess secondary to ruptured pyosalpinx; perforation of peptic ulcer and subphrenic abscess.

(iv) *By inhalation*, e.g. of contaminated cough spray producing pneumonia with acute abscess; of aspirated septic material producing inhalation pneumonia and abscess.

(v) *By lymphatic extension* from a focus of infection under (i), (ii), (iii) or (iv), producing acute suppurative lymphadenitis with acute abscess in a regional lymph gland.

(vi) *By venous involvement* commencing as acute thrombophlebitis and producing a local acute abscess or general venous dissemination by septic embolism and septic infarction. Infected emboli may reach the lung producing venous pyaemia, or, originating in the portal system, may reach the liver producing portal pyaemia, e.g. multiple acute pulmonary abscesses complicating puerperal endometritis, acute staphylococcal osteomyelitis or acute mastoiditis; multiple acute abscesses in the liver from thrombophlebitis of the appendicular veins in acute appendicitis.

Embolic dissemination

(vii) *By bacteriaemia, septicaemia and arterial pyaemia.* The abscesses tend to be small and multiple in septicaemia and arterial pyaemia. They are larger, fewer and may be localized to one tissue in bacteriaemia, e.g. multiple visceral abscesses in acute endocarditis; brain abscess secondary to bronchiectasis; staphylococcal abscess of the kidney and acute staphylococcal osteomyelitis with subperiosteal abscess both of which are secondary to temporary staphylococcal bacteriaemia.

3. EVOLUTION

(1) General outline

The following is an outline of the sequence of events leading to the formation of an acute abscess:

(a) Proliferation and local dissemination of bacteria.

(b) An acute inflammatory reaction, characterized by capillary dilatation, exudation of plasma and inflammatory oedema and probably produced by chemical substances liberated as the result of tissue damage caused by toxic bacterial substances.

(c) Rapid transformation of this lesion by continuous emigration into it of relatively enormous numbers of polymorphonuclear leucocytes often necessitating the discharge from the bone marrow of its emergency stock of mature leucocytes.

(d) Early localization of the lesion by a temporary defence barrier.

(e) Continued emigration of leucocytes and phagocytosis of bacteria often giving rise to a polymorphonuclear leucocytosis in the blood, maintained by a leucoblastic reaction of the bone marrow.

(f) Wholesale death and rapid autolysis of emigrated leucocytes with liberation of leucocytic enzymes.

(g) Liquefaction of all constituents of the tissue in which the lesion lies by proteolysis and lipolysis with the production of pus.

(h) Appearance of granulation-tissue—a living defence barrier composed of proliferating vaso-formative mesenchyme.

(i) Consolidation of the granulation-tissue barrier.

(2) Leucocytic emigration. Chemotaxis

The tissue damage which initiates the process of suppuration is probably due to soluble and diffusible toxic substances derived from the proliferating bacteria. One of these, the α-toxin produced by staphylococci, is of particular interest in the formation of acute abscess. It causes rapid and acute necrosis of tissue, and is present in the bacterium-free filtrates of coagulase-positive staphylococci. Bacterial products such as this may play a part in producing the tissue damage leading to the initial acute inflammation, and may also provide the tissue breakdown products which exert positive chemotaxis at the next stage.

α-Toxin of staphylococci

We have little knowledge of the mechanism of chemotaxis, the force which attracts polymorphonuclear leucocytes to the invading bacteria, but it is generally agreed that chemotactic agents are protein breakdown products, and are present in damaged cells and tissues including skin and muscle. They have been found in wounds and burns.

Protein breakdown products

Menkin (1940) claims that the leucocytic emigration in all acute inflammations is due to leukotaxine, a breakdown product formed at the site of inflammation, and found not only in the exudate of acute bacterial inflammation but also in areas of tissue damage produced by scalding and the application of turpentine or croton oil. He has isolated this substance in crystalline form. It is extremely potent and powerfully chemotactic. It has no chemical relationship with the H-substance of Lewis or with nucleic acid, pentnucleotides or adenosine. Menkin's work has been confirmed by Duthie and Chain (1939).

Leukotaxine

Quite unlike bacterial phagocytosis, the chemotactic response of leucocytes is not altered by the acquisition of immunity (McCutcheon, 1942). It lacks the specificity of the immunity response, and is a more primitive biological mechanism than antibody formation. There is no increase in its speed or duration in the immune as opposed to the susceptible animal nor does the addition of immune serum accelerate it *in vitro*.

Chemotaxis and immunity

(3) Source of leucocytes

In the early stages of the formation of an acute abscess of any size the circulating blood alone would be incapable of providing an adequate number of granulocytes without serious depletion in its own number. The proliferation and ripening of myelocytes in the marrow which constitutes the leucoblastic reaction does not commence for approximately thirty-six hours, and until this process is under way there must be a free discharge into the blood of mature granulocytes held in the marrow as an emergency stock. It is usually assumed, although by no means proved, that the same protein breakdown products which attract the circulating haemal leucocytes to the inflamed area are carried by the blood-stream to the marrow and exert a similar effect on its *mature* leucocytes. In addition to this, however, the discharge of these cells must entail a widespread vascular response in the marrow, for myelocytes and leucocytes lie closely packed *outside* the marrow capillaries in which the rate of blood-flow is slow. The vascular response must thus give rise to considerable acceleration of blood-flow through the marrow and facilitate the rapid emigration of mature leucocytes through the marrow capillaries. Leucocytic emigration and suppuration cannot take place in the absence of this response together with a leucoblastic reaction of the marrow. These reactions may therefore be properly regarded as integral parts of the process of suppuration.

Vascular response in the marrow

(4) Localization of infection

Early localization of an acute suppurative inflammation, the essential event in acute abscess formation, is a complex process. It may, on the one hand, depend upon the character of the micro-organism itself, i.e. on its inherent inability to spread through normal tissues or through a cellular or fibrinous barrier produced by the reacting tissue. On the other hand, it may depend upon a reaction of the tissues which, in the early and vital stages of localization, may lay down a mechanical barrier around the bacteria, or produce antibodies which immobilize the micro-organisms by agglutinating them, or by keeping their numbers in check by bacteriostasis, bacteriolysis or phagocytosis.

Possible mechanisms

(5) Hyaluronidase. Fibrinolysin. Coagulase

Some highly invasive bacteria such as *Cl. welchii* set free into the medium in which they are growing considerable quantities of an enzyme, *hyaluronidase*, a protein-free polysaccharide capable of breaking down hyaluronic acid, a normal constituent of the mucinoid matrix of connective tissues. Hyaluronic acid preserves the normal gel-like consistency of tissue matrix. In its absence, connective tissue becomes less viscous, more freely flowing and therefore more permeable to invading bacteria.

Production of hyaluronidase

If hyaluronidase production by bacteria plays a predominant part in the diffusion of infection, the highly invasive strains of β-haemolytic streptococci

should possess this property whilst, as a general rule, the coagulase-positive staphylococci should not. This is not so. Schwabacher and her colleagues (1945) have shown that the large majority of a considerable number of strains of pathogenic staphylococci produce hyaluronidase. On the other hand, Duran-Reynals (1942) has shown that a series of strains of staphylococci could be grouped according to the surface area of the lesions they produced and that this grouping could be correlated with the hyaluronidase formation. This problem needs further quantitative investigation, but, as it stands, it does not appear that the production of this ferment provides a complete answer to the problem of localization.

(6) Fibrin barrier. Agglutination

It is in the early hours of infection before the tissue defences are mobilized that localization is most vital. According to Menkin early localization is due to the formation of a barrier of fibrin between the focus of inflammation and the normal tissue around it. The effectiveness of the barrier is, he considers, determined by the speed at which the fibrin is laid down and this in its turn is determined solely by the degree of local tissue injury.

Menkin's views attach no importance to certain specific and highly reactive soluble bacterial products which may play a large part in the production or disruption of the fibrin barrier in pyogenic inflammation. Streptococci causing diffuse inflammation usually produce a powerful fibrinolysin, and it is difficult to escape the conclusion that this aids in their diffusion. Staphylococci do not produce fibrinolysin and this may partly explain their tendency to remain localized. Pathogenic staphylococci, on the other hand, excrete coagulase which rapidly coagulates plasma, and may materially assist the rapid formation of an efficient defence barrier in the early hours of acute abscess formation.

Fibrinolysin

Coagulase

Role of bacterial agglutination

Rich (1936) considers that localization is largely conditioned by immobilization of the bacteria brought about by specific agglutination, this process progressing until the masses of clumped bacteria become fixed in the tissue, largely by virtue of their size.

Both Menkin and Rich produce impressive, but by no means conclusive, experimental evidence in support of their contentions. Menkin claims to have discovered the mechanism which controls localization in all inflammatory reactions, its effectiveness varying only with the amount of tissue breakdown. Rich regards localization as a specific process, the result of interaction between antibody and antigen and based on the possession or rapid acquisition of specific immunity to the invading bacterium.

(7) Leucoblastic reaction of marrow

The excessive demand for granular leucocytes during the evolution of any large or medium-sized acute abscess is met in the first place by a discharge from the marrow of its emergency stock of mature white cells, and by the accelerated ripening of partly differentiated myelocytes. This process may well be stimulated by protein breakdown products occurring in the inflamed tissue and Menkin has isolated a pseudo-globin from inflammatory exudates which has this action. The maintenance of the sustained leucocytosis of acute suppuration is, however, a totally different process. This involves the proliferation by mitosis of primitive undifferentiated cells. It is a clear example of

Menkin's leucocytosis-promoting factor

hyperplasia and, judging from other hyperplastic processes, the stimulus producing it is probably a chemical one and is likely to have a physiological basis. There are several good reasons for supposing that nucleic acid or a closely allied substance provides this stimulus to mitosis. Substances of this group produce a marked leucoblastic reaction in normal animals. They must be constantly produced under physiological conditions as the nuclei of senile leucocytes disintegrate in the tissues, and are almost certainly produced in excessive amounts by the action of the nuclease liberated from autolysing leucocytes during the process of suppuration.

Role of nucleic acids

(8) Leucocytic destruction

The process of acute abscess formation has been described as far as the focal accumulation of a large number of emigrated leucocytes in the depths of a tissue. The next essential step is the rapid and wholesale killing of these cells. A polymorphonuclear leucocyte which has emigrated into a normal tissue must have a life span of a few hours at the most, and the majority of those which crowd into a focus of suppuration must die rapidly, partly because of their unsuitable chemical and physical environment and partly from attack by toxic bacterial products. One such substance, staphylococcal *leucocidin*, is known to have a specific lethal effect on leucocytes, and is apparently quite distinct from the α-toxin produced by the same micro-organisms. It may well be that the capacity to produce a specific leucocidin explains in part the strong tendency of the coagulase-positive staphylococci to produce localized suppuration. The scale on which leucocytes are destroyed obviously depends upon the speed at which the bacteria are proliferating in the lesion, altering the physical and chemical conditions within the lesion and liberating toxic metabolites.

Staphylococcal leucocidin

(9) Liquefaction. Pus formation

We now reach the final phase. The wholesale death of leucocytes is followed by rapid autolysis of their cytoplasm and a complex mixture of cytoplasmic enzymes previously locked up in these cells is liberated into the inflamed tissue. The fact that polymorphonuclear leucocytes can actually digest bacteria strongly suggests that they contain proteolytic enzymes, and there are a fair number of accurate observations published which show that polymorphonuclear leucocytes contain considerable quantities of trypsin, nuclease, amylase, lipase and cathepsin. All the tissue elements lying within the focus are rapidly liquefied, and the soluble end-products, peptones and polypeptides, fatty acids and soaps, are added to the inflammatory exudate. The opaque fluid or pus which now entirely replaces the infected tissue is thus composed of living, dying or dead and autolysing leucocytes lying in an inflammatory exudate composed of blood-plasma diluted with tissue fluid and containing the end-products of liquefaction of the tissue together with living and dead bacteria lying either free in the exudate or inside the bodies of leucocytes.

Autolysis of leucocytes

Leucocytic enzymes

Pus

4. GRANULATION-TISSUE BARRIER

At a relatively early stage in the evolution of an acute abscess and before central liquefaction is complete, the fibrin barrier becomes autolysed and is replaced by a living, growing and organized tissue composed of angioblastic

mesenchyme containing myriads of primitive capillary blood-vessels and proliferating fibroblasts. This is granulation-tissue. Solid buds composed of vasoformative endothelial cells (angioblasts) sprout from the walls of the tissue capillaries and push forward to the extreme edge of the area of leucocytic infiltration and softening. They join to produce loops which become canalized by vacuolation of their central cells. These primitive capillaries lie at first in a gel-like matrix probably derived from plasma protein. Rapidly proliferating fibroblasts lie in close apposition with their walls.

Functions

The granulation-tissue barrier develops and increases in thickness *pari passu* with the process of liquefaction in the abscess. It may be regarded as a fertile formative tissue solely concerned with healing or as a living barrier forming an integral part of the defence process but eventually providing an undifferentiated tissue which lays the foundation for repair. Whatever its true significance may be, there is little doubt that the *granulation-tissue barrier around an acute abscess limits the spread of infection, is often called upon to resist actual bacterial invasion and frequently repels it.*

5. OUTCOME

(1) Resolution

"Pyogenic membrane" and "sloughs"

Naked-eye examination of the inner wall of an abscess cavity often shows it to be lined with a friable, shaggy, grey membrane ("pyogenic membrane") composed of necrotic tissue not yet completely liquefied, and not infrequently heavily infected by bacteria. In some instances the amount of undigested necrotic "slough" lying adherent to the wall of the abscess or free in the cavity is considerable. This material, out of reach of the circulation and heavily infected, cannot be reached by penicillin and bacteriostatic agents and suppuration continues unless it be completely removed. Outside this zone the signs of inflammation become less conspicuous and in the outermost zone are often absent.

(2) Invasion of granulation-tissue

Secondary localization

If the granulation-tissue fails to resist invasion—and this usually takes place before an efficient barrier is laid down and when bacteria are freely multiplying—the whole thickness of the granulation-tissue becomes pierced at few or many points by finger-like processes composed of closely packed leucocytes. As these push forward into the tissue they are in turn held by a barrier, at first composed of fibrin, coagulated plasma and reacting tissue mesenchyme, and later by a granulation-tissue envelope. In this way an acute abscess increases in size and may very considerably alter its shape by the development of extensions and loculations.

(3) Loculation

Loculation is often an obstacle to successful treatment of acute abscess by penicillin and bacteriostatic drugs. It is prone to occur in glandular tissues such as the breast where it is complicated by the occurrence of multiple ruptures into the duct system with extensive spread and "burrowing".

(4) Diffusion of infection

If these penetrations of the granulation-tissue are not localized there is a risk of free dissemination of infected purulent exudate into the tissue. The acute abscess then becomes the centre of an area of diffuse suppurative inflammation. This complication is liable in any situation to give rise to free dissemination of bacteria by lymphatics with the possibility of acute suppurative lymphadenitis with or without acute abscess formation in the regional lymph glands.

(a) Rupture

The granulation-tissue which encloses an acute abscess is called upon to withstand another force which tends to destroy its continuity. This is the *considerable and increasing hydrostatic tension exerted in all directions by* the contents of the abscess when total liquefaction has transformed this into a sphere of fluid of constantly increasing volume imprisoned in solid tissue. This internal tension alone may lead to rupture which may be precipitated by pressure, trauma or violent muscular contraction.

(b) Tracking pus

Rupture into the tissue itself will disseminate infective exudate at considerable force along the line of least resistance and the "tracking pus" will travel considerable distances until it is discharged to the exterior or ruptures into a duct, space, sac, hollow viscus, cavity or blood-vessel. Rupture of an abscess may lead to spontaneous cure provided the pus is discharged to the exterior and the point of rupture is favourably situated for the free discharge of all contaminated material. Failing this, suppuration will continue. The track to the surface is then enclosed in a sleeve of granulation-tissue and often becomes secondarily infected. It is often tortuous and liable to become intermittently obstructed with the risk of the formation once more of pus under tension, and the danger of rupture at another and perhaps more dangerous point.

Complications

Rupture into a space or tube may cause innumerable complications, some of the more serious being a general peritonitis, acute meningitis, acute arthritis and acute osteomyelitis. *These complications are determined by the* situation of the primary lesion.

(5) Thrombophlebitis

It must, however, be constantly borne in mind that any acute abscess in any situation may involve the wall of a near-by vein with the production of acute thrombophlebitis and the grave risk of venous pyaemia. This risk is obviously greater in organs such as the uterus and prostate which contain venous plexuses, the vessels of which are tortuous and thin walled, and which not infrequently become varicose and have a pronounced tendency to undergo thrombosis.

6. APPLICATION TO TREATMENT

In the majority of instances bacteria can be seen in films made from the pus of an acute abscess. They can be cultivated from it in the large majority of cases even when the results of film examination are doubtful. Enriched nutrient media may be needed, and it is sometimes necessary to incubate the cultures anaerobically or in an atmosphere containing 5 per cent carbon dioxide.

It must, therefore, be assumed that the pus of an acute abscess is a highly infective fluid and always contains living and viable bacteria. For this reason an acute abscess must always be regarded as a surgical emergency and, in spite of the brilliant results obtained by the use of penicillin and the bacteriostatic drugs, every well-established and deeply seated abscess containing pus under tension and liable to spontaneous rupture calls for free incision and adequate drainage.

This is all the more necessary when the cavity is loculated or the pus is "burrowing" and when there is any likelihood that the cavity may contain infected sloughs which are out of reach of the circulating blood. It is possible, however, to arrest the further development of an acute abscess at an early stage if the patient is given adequate systemic treatment with penicillin. Even then an incision must be made in the lesion to relieve tension, and it must be borne in mind that free drainage is urgently called for unless there are clear indications of rapid and satisfactory resolution.

In view of the enormous help to be expected from treatment with penicillin and the bacteriostatics, a full bacteriological examination of the pus from all acute abscesses, unless small and superficial, should be carried out as soon as possible. This examination must, of course, include tests to determine the sensitivity of the cultivated micro-organism to penicillin and the appropriate sulphonamides.

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[References to other titles are given under Abscess in the Index Volume.]

ACHLORHYDRIA AND APPETITE

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1. APPETITE

6.] It must be seldom indeed that the surgeon is consulted for disturbance of appetite. The rare condition of bulimia, although generally of mental causation, has been attributed on at least one occasion, cited by Clifford Allbutt, to a neuroma of the vagus which was cured by excision. *Hyperorexia*

Loss of appetite, whether of physical or psychical origin, is a functional disturbance which depends upon so many possibilities for disturbance of health that it is only an incident in any surgeon's experience, one which he is bound to expect as inevitable, and is prepared to treat on orthodox lines or with the co-operation of a colleague to whom such a symptom is a commonplace of his professional responsibility. *Anorexia*

In carcinoma of the stomach, anorexia is advanced as a familiar expectation. It is perfectly true that the sudden appearance of loss of appetite, which may amount to something more obtrusive than an indifference to food, indeed to a positive loathing or even to a sitophobia, has long been recognized as a suspicious feature even in the absence of any other indication of a gastric lesion. Other familiar causes for the symptom have first to be considered. Psychical possibilities are only too likely under modern conditions of stress and strain. On the other hand, advanced malignant disease may be encountered when the appetite remains unimpaired to the end. At one time a peculiar distaste for meat was regarded as especially significant of gastric carcinoma. I doubt if this peculiarity is outstanding; the anorexia more usually includes meat in common with food generally. *Carcinoma of the stomach* *Other causes*

In the post-operative state of extensive gastrectomy disturbance of appetite may be advanced, but this is not so much an anorexia as a rapid sense of satiety which is only to be expected when the reduction in size of the viscus is regarded. With gradual hypertrophy of the residual stomach the symptom ameliorates. Rarely, fistulous communication, with unduly rapid emptying of the stomach, might lead to the opposite condition of incomplete satiety, but in such a condition the general ill health that ensues would be likely to impair the appetite. *After gastrectomy*

2. ACHLORHYDRIA

There is, unfortunately, some confusion in the use and interpretation of this term, as of others regarded as synonymous. In the first place it is best to eliminate such supposed alternatives as anacidity and achylia gastrica. In respect to the last named, when one considers the varied constituents that may be present in gastric juice it may well be doubted if its complete suppression ever occurs. Achlorhydria means absence of free hydrochloric acid, yet even so, some enquiry concerning its exact meaning is pertinent. Do we mean that there *Anacidity and achylia gastrica* *Meaning of achlorhydria*

is no reaction to Congo red or to Töpfer's solution? Or that the juice has a *p*H of 3·5 or over? Do we on occasion precociously accept a temporary absence, or have we satisfied ourselves that the stomach really is incapable of secreting free hydrochloric acid even under maximal stimulation, for example by histamine?

Associated conditions

A variety of conditions seem to be associated with achlorhydria. Among these may be mentioned Addisonian (pernicious) anaemia, other forms of anaemia, gastric carcinoma, chronic gastritis, gall-bladder disease, toxic goitre, tuberculosis, alcoholism, sprue, pellagra.

The constitutional factor

Apart from all ascertainable lesions, a small percentage of stomachs—perhaps 1–1·5 per cent—exhibit a constitutional achlorhydria.

Irritative factors

Hurst's view will be recalled that all human stomachs are subject to the influence of chronic irritants—infection, dietetic, trauma, alcohol, tobacco—and that 80 per cent tolerate these various insults. Hurst believed that in 10 per cent there will develop hyperchlorhydric gastritis, which leads to ulceration, and in 10 per cent an achlorhydric gastritis with the development of anaemia or carcinoma. Presumably some constitutional factor determines why some react to hyperfunction and some to hypofunction. The practical consequence is that the discovery of achlorhydria and the appropriate treatment—eradication of sepsis, avoidance of dietetic irregularities, of alcohol and tobacco, the administration of iron, liver and hydrochloric acid—might lessen the incidence of gastric carcinoma, of severe anaemia and the other conditions above-mentioned.

Treatment

[References to other titles are given under Achlorhydria in the Index Volume. The subject of Achlorhydria is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 126.]

ACIDOSIS

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1. DEFINITION

A symptom not a disease

7.] Acidosis is a manifestation of an altered physiological state in which the blood and tissue fluids generally are more acid than they are in their normal condition; clinical effects are produced before there is a measurable change in blood reaction and indicate a reduction in the buffering power of the plasma and tissue fluids.

2. AETIOLOGY

Internal environment

The condition of the environment of the cells, that is to say the temperature and constitution of the fluid content of the body, must be kept within reasonably narrow favourable limits in order to ensure the removal of waste products; these are largely acid in reaction. From the surgical point of view the inhibiting factors in this respect are mainly dehydration, anaemia, fever and infection and defects in the organs of elimination, all of which may have a profound effect on the acid-base balance.

3. PHYSIOLOGY

Acid-base balance

The reaction of the blood is determined by the ratio of free carbon dioxide to combined carbon dioxide. The former is a weak acid and is dissolved in the blood as carbonic acid; the latter is a weak base in the form of sodium bicarbonate. The ratio of these two is normally kept as constant as possible, carbon dioxide being given off by the lungs and unwanted salts being eliminated by the kidneys.

The reaction of the blood is expressed in terms of its hydrogen-ion content, or more conveniently by its negative logarithm, *p*H. The *p*H of a neutral solution is 7; that of the blood is 7·4. The blood, therefore, is slightly alkaline and is, as it were, ready for the products of metabolism which are acid. Extra base is always available for the purpose of neutralizing metabolites, whereby salts are formed and excreted by the kidneys. The more acid the blood the lower the *p*H figure, and vice versa; the normal limits set to this plasma carbon dioxide combining power are 53 to 77 volumes per cent. Beyond these limits the position is uncompensated, and if this is not speedily adjusted death will ensue from either acidosis or alkalosis.

When there is greater acid formation during excessive physiological processes the lactic acid so formed is dealt with by buffering, as follows.

(1) Sodium bicarbonate and lactic acid = sodium lactate, water and carbon dioxide.

(2) Alkaline sodium phosphate and lactic acid = sodium lactate and acid sodium phosphate.

Oxyhaemoglobin is a weak acid and with its salt forms the most important buffer system in the erythrocyte. If the concentration of acid in the plasma increases, some diffuses into the erythrocytes and becomes neutralized by base liberated from haemoglobin. Non-volatile acids are buffered in the same way as is lactic acid and are then excreted as sodium salts. If, however, they are formed in such quantity as to reduce the alkali reserve, ammonia is formed from urea by the kidneys so that the acids can be excreted as ammonium salts, thus economizing in sodium base. This process can be effectively carried on only when the kidneys are reasonably efficient, a circumstance closely associated with water balance.

Ketosis

Ketosis may or may not coexist with acidosis. It is due to poor fat combustion which may result from inability of the body to utilize available carbohydrate, or from insufficient carbohydrate intake. Ketone bodies (β-hydroxybutyric acid, acetoacetic acid and acetone) accumulate in the blood and are found in the urine. It is often impossible to decide whether the acidosis is purely the result of the presence of these ketone bodies or of other acid products of metabolism. It is, however, important to determine whether or not ketosis exists, especially in diabetes mellitus, in which the ketone bodies may be present in sufficient amount to produce acidosis; in these circumstances surgery is almost inevitably fatal.

Diabetes

4. SYMPTOMS

Alkali deficit

The most important clinical variety of acidosis is due to primary alkali deficit resulting from either alkali loss or acid retention. Acidosis should be kept in mind, therefore, when conditions are present which may be responsible for either of these, for example prolonged diarrhoea, or intestinal fistulae which may carry off much of the alkali secreted into the upper intestinal tract and normally would be reabsorbed. In certain degenerative conditions of the kidneys chlorides may be retained, just as they are in the depressed function caused by blood concentration. It should be noted that many of the conditions which predispose to acidosis are associated with excessive loss of fluid. The following are important in this respect;

Predisposing factors

(1) Haemorrhage, external and internal.
(2) Shock, acute and chronic (circulatory failure).
(3) Loss of fluid via the intestinal tract on account of:
  (a) vomiting
  (b) fistulae
  (c) intestinal obstruction (even apart from vomiting).
(4) Fluid loss from metabolic diseases, for example diabetes mellitus.
(5) Protein loss in burns and in long-continued suppuration.
(6) High fever.

It is worth noting that these conditions, however dissimilar they may at first appear to be, have fundamentally the same constitutional effects and require the same general treatment. From the surgical point of view dehydration is the really important factor in initiating the biochemical disturbances referred to above. It is essential, therefore, to recognize the position and to be able to form an idea of the degree of water loss.

Dehydration

The advanced stages of dehydration are plainly visible: dry tongue, dry furred teeth, sunken eyeballs, dry inelastic skin, thirst, scanty urine; but considerable water loss may be present long before these signs are apparent. The flow of water occurs between the blood and the intracellular and extracellular spaces, although as dehydration continues the intracellular water is less readily yielded up. Nevertheless it is safe to assume that in most cases both intracellular and extracellular spaces are depleted to much the same extent. Determination of the water content of the cells and of the extracellular spaces is impracticable; in the case of the blood, however, it can be made, and the degree of concentration here may be used as a general guide to what is happening in the more remote areas.

The fully developed case

A fully developed case of acidosis shows the following symptoms: hyperpnoea (at first deep rather than rapid breathing, without evident cyanosis); usually, except in diabetic coma, an exaggerated state of awareness; always dehydration and a quickened pulse. Headache, nausea, vomiting and dyspnoea may occur later. By the time hyperpnoea appears, the alkali reserve is seriously depleted. The air hunger in cases of severe diabetes is very noticeable, and the odour of acetone in the breath and in the sweat may be detected.

5. DIAGNOSIS

In the incipient stages recognition of acidosis is not easy, although it may be clear that there is something amiss with the patient especially when the condition is developing after operation. Recognizable symptoms appear as the condition progresses, and at this stage treatment may be too late. Every method should be employed which can assist in proving the presence of acidosis before it becomes uncompensated. The following tests are available:

Hydrogen-ion concentration of blood

(1) The conclusive proof of uncompensated acidosis is a fall in the hydrogen-ion concentration of the blood. By the time such acidosis is demonstrable the clinical condition is desperate and the test is of no practical use.

Alkali reserve

(2) The most serviceable and practical test is the determination of carbon dioxide combining power, or of alkali reserve, which varies from 53 to 77 volumes per cent. Values below 35 indicate severe acidosis. The test is reasonably simple but it is unsafe to rely on a single estimation.

(3) The urine may be tested for the secretion of nitrogen as ammonia. The more acid to be excreted the more ammonia is needed for neutralization and consequently the greater the ammonia content of the urine. This test depends upon the kidneys being normally efficient, and upon certain other variable factors which make the test troublesome to control.

Rothera's and Gerhardt's tests

(4) Although ketosis may be present without acidosis, the former usually implies the latter; in this case easily performed tests such as Rothera's and Gerhardt's are helpful. Certain drugs (phenol and the salicylates) give a similar reaction, but if this possibility is borne in mind mistakes are unlikely.

Dehydration

(5) Dehydration is often the underlying cause of acidosis; its presence can be determined by estimating the urinary output and its specific gravity. Dehydration is negligible if the urine totals 1,000 cubic centimetres in twenty-four hours and has a specific gravity of 1·020–1·030. A daily total of 600 cubic centimetres or less of urine of high specific gravity in the absence of kidney disease indicates water shortage, and in such a case nitrogen retention will occur and will be demonstrable as a rise in the blood-urea from the normal lower level of 20 to the normal upper limit of 40 milligrams per cent; a rise above this suggests dehydration. Daily estimations of urinary output and of specific gravity together with daily estimations of blood-urea and haemoglobin values will give reasonably reliable information concerning the degree of dehydration and its response to treatment.

Diabetes mellitus

(6) In diabetes mellitus tests for ketonuria are essential; if ketone bodies are present the alkali reserve must be determined.

6. DIFFERENTIAL DIAGNOSIS

Pneumonia

The superficial resemblance of the breathing in acidosis to that in pneumonia may direct attention to the lungs rather than to the acid-base balance, with disastrous results since the treatments are so different. Closer attention to the breathing shows that in pneumonia respiration is rapid and shallow with an expiratory grunt, and there is cyanosis, whereas in acidosis breathing is deep, and is only slightly increased in rate and cyanosis is not evident until late. Coupled with a knowledge of these differences, the ordinary signs of pneumonia elicited by clinical methods should be sufficient to prevent mistakes.

Generally speaking, acidosis is a symptom in many different kinds of disease; the question of differential diagnosis is concerned, therefore, with the primary condition. It should be kept in mind that acid-base imbalance may occur as an additional factor—an important one, it is true, but only incidental in the progress of the primary lesion.

7. COURSE AND PROGNOSIS

In surgical practice acidosis, when it develops, does so most often because there is a primary condition inducing dehydration. It is most important to realize this fact since surgical operation itself produces some dehydration, and when it is undertaken in the presence of existing water imbalance it is likely to precipitate in the patient a considerable disturbance of acid-base equilibrium which, on reflection, is obvious. During operation the patient loses a certain amount of blood; under anaesthesia he may lose a large amount of fluid by sweating and by breathing deeply, and additional loss will occur by evaporation from exposed viscera. After operation he may sweat freely; he may vomit and ingested fluids will be restricted; if tubes are inserted fluids and protein will be lost. It is quite usual for the fluid content of the tissues to be depleted in these various ways by as much as 1,500 cubic centimetres in twenty-four hours and occasionally by a great deal more. There is therefore a serious threat of dehydration after any major operation, but in a patient already handicapped by water loss it is impossible to exaggerate its seriousness. There is competition for water between the tissues and the kidneys. It is an unequal competition since the tissues cling fast to the diminishing supply

Disturbance of acid-base equilibrium

Depletion of fluid content

in order to maintain tissue respiration; the kidneys get what they can. The diminishing urinary output leads to retention of waste (acid) products, which in turn further hampers internal respiration. The blood itself suffers, becoming thicker and more viscous; it flows less easily, thereby increasing the difficulties of efficient oxidation and general metabolic exchange. There is established, in fact, a vicious circle tending all the time towards increase of acidosis. It is clear, therefore, that diseases accompanied by fluid loss must be investigated from the point of view of fluid balance before operation is undertaken. This can be done by applying the methods given above under Diagnosis.

Retention of waste products

A vicious circle

8. TREATMENT

For practical surgical purposes it is true that acidosis is unlikely to occur if attention is paid to the maintenance of fluid balance.

Fluid balance and loss

Normally, fluid balance is maintained as follows. Water is being lost continually day and night by the following main routes:

(1) The lungs: about 500 cubic centimetres.
(2) Insensible loss from the skin: about 1,000 cubic centimetres.
(3) The kidneys: about 1,500 cubic centimetres.

There are one or two minor outlets and it is a fair estimate to put total water loss in twenty-four hours at 3,500 cubic centimetres.

Fluid intake

Normally all fluid is taken in by the mouth and is therefore easily estimated. An additional supply of about 500 cubic centimetres is derived from oxidation of carbohydrates and fats.

In quiet conditions fluid balance remains stable, but during muscular exertion and excitement and when, for example, the temperature is high, much larger quantities will be lost by sweating and by increased respiratory excursion. In these circumstances the kidneys excrete a concentrated urine in order to conserve water for the all-important internal respiratory mechanism. Normally the call for water is remedied by increased intake invoked by thirst, and balance becomes restored.

Commonly, the administration of abundant quantities of fluid with glucose and salt (sodium chloride) is indicated when acidosis is suspected or proved, or when surgical measures are contemplated which will hasten fluid loss and so tend to increase acidosis.

Fluid requirements

The daily loss of fluid by the routes mentioned must be assessed, and to the result must be added any further loss, for example by vomiting or diarrhoea. The intake must be made to balance the total loss. In addition, the deficit incurred before the patient has come for treatment must be taken into account. This is not so easy to calculate, but it has been determined that a patient showing clear signs of dehydration will lose about 6 per cent of his body weight; if he weighs ten stone he needs, therefore, some 3,500 cubic centimetres over and above his maintenance requirement of 3,500 cubic centimetres, a total of 7,000 cubic centimetres. If, as so often happens, this extra fluid has to be given parenterally, it should be run in slowly over a period of several days. At first urinary secretion may be little affected, but when it rises to 1,000 cubic centimetres or more it is evidence that the fluid reservoirs are being satisfactorily replenished, and the fluid intake can be gradually reduced to maintenance level.

The natural channel is the best method of giving fluid, and drinks should contain large quantities of glucose. For various reasons, however, fluid may not be taken or retained in sufficient quantities in this way, and it should then be administered parenterally. When given thus it should be isotonic; if it is hypotonic it will not be retained, and if it is hypertonic it will increase dehydration by osmosis.

Parenteral administration

Type of fluid given

The fluid should be normal saline with 5 per cent glucose; Ringer-Locke solution and Hartmann's solution have been used, but in practice they are not more efficacious than is normal saline. The amount of salt administered must be watched; the normal average daily intake of sodium chloride is about 15 grammes; if 4,000 cubic centimetres of normal saline be administered there would be more than double this amount of salt, much of which the kidneys would have to excrete, and they may be embarrassed already, apart from this extra work. It is preferable, therefore, to make up the solution in the proportion of one part of normal saline to 4 parts of 5 per cent glucose. Glucose is an essential ingredient in the maintenance of a patient who is having fluids administered parenterally; it is completely metabolized to carbon dioxide and water in the presence of insulin and so strain is not put on the excretory organs; it is an essential foodstuff and can be added easily and safely to the blood. When it is given in sufficient quantities glucose is stored in the liver as glycogen and so protects this organ against hepatic irritants of which, in acidosis, there are many in the blood. Moreover, glucose is a protein sparer, it is necessary for the complete combustion of fat and so is beneficial in the prevention and treatment of ketosis. For the purpose of ensuring its complete utilization insulin may be given in the proportion of one unit of insulin to every 2 grammes of glucose.

Glucose

Oedema

Should dehydration be overcorrected there is, in patients with marked wasting, a tendency towards the development of oedema. This is probably due to production of an absolute deficiency of proteins in the blood with a diminution in water-holding capacity in the plasma. Prolonged suppuration also will bring about protein loss. In this case the fluid which is given in the earlier stages of acidosis should be supplemented by parenteral administration of plasma.

Blood transfusion

As a rule, blood transfusion is not indicated in acidosis because there is concentration of corpuscles in the peripheral areas of the circulation and additional corpuscles will still more embarrass the peripheral circulation.

Oxygen

The administration of oxygen in a tent or through a mask is very helpful.

There are three methods of introducing fluids when they cannot be given by the mouth—the subcutaneous, the rectal and the intravenous.

Methods of giving fluids parenterally

(1) The subcutaneous method. This is apt to be painful, especially when the fluid contains glucose; absorption is slow and uncertain. The method is seldom used now.

(2) The rectal method. In dealing with a condition like acidosis it is essential to know how much fluid is being taken into the blood-stream. It may happen that after some hours of administration of fluid into the rectum a large quantity is returned. A reliable record of what is actually absorbed cannot be made and thus much time may be wasted. For this reason rectal infusion is not advisable. Moreover, strong solutions of glucose irritate the mucosa and interfere with absorption.

(3) The intravenous method. This is the only reliable method, and each type of fluid recommended above can be safely and accurately delivered in the certain knowledge that all of it will reach the circulation. If fluid has to be given over a period of several days and especially when it contains glucose, the vein may undergo a sclerosing endothelial inflammation which will be painful and will stop the flow. The remedy is to use another vein.

Apparatus

The apparatus which is employed for administration of fluids intravenously is well known. It is simple and should be of the type which delivers the fluid drop by drop. Since the number of drops which fall per minute is known it is an easy matter to calculate the quantity delivered in twenty-four hours and to regulate the inflow to meet the estimated needs.

In my experience nothing is gained by adding sodium bicarbonate to the fluid. The sodium chloride provides all the base required and is much safer.

Diabetes

Any surgical lesion may occur in a diabetic subject, but carbuncle, cellulitis and gangrene are especially likely to do so, causing a dangerous swing towards acidosis. In the treatment of these patients all the methods indicated above find a place, but the use of insulin in addition is essential. With time and care it is possible materially to reduce the risks of operation on diabetic patients, so much so that those whose disease is uncomplicated by septic lesions run very little more risk than do non-diabetic subjects.

Emergency cases

Time may be short, however, when there is any ordinary surgical emergency or when severe sepsis is present. Even in such an event it is worth while to devote a few hours to preparation. To prevent hypoglycaemia these patients need adequate quantities of insulin and sufficient glucose (in the ratio of one unit of insulin to 2 grammes of glucose at short intervals before operation and at four-hourly intervals thereafter). The glucose may be given by the mouth, or an equivalent dose may be administered by the continuous intravenous drip method before, during and after operation. Twenty units of insulin with 40 grammes of glucose is an average dose.

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ACTINOMYCOSIS

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1. DEFINITION

8.] Actinomycosis is the name given to the pathological condition resulting from the growth in animal tissues of a micro-organism known as the actinomyces or ray fungus—so called because mycelial threads can often be seen radiating from the main mass of the fungus. The same organism is variously referred to in the literature as discomyces, oospora, nocardia, streptothrix and cohnistreptothrix.

2. AETIOLOGY

Description of common species

The Actinomyces is a genus of fungus showing a branching mycelium which may break into segments of varying length. The genus comprises many species which may be either saprophytic or parasitic; when the micro-organism occurs in the latter form in animal tissues there may be clubbing of the ends of the radiating threads. The common species which are to be found almost everywhere in nature, and particularly on grasses, grains and decaying vegetable matter, are hardy organisms growing freely on ordinary media at normal temperatures when exposed to the air; they are seldom pathogenic.

The less common type, which is in most cases the cause of disease in animals, is a delicate organism which soon dies when exposed to ordinary temperatures, and will grow only on special media (for example, glucose-agar) when the oxygen supply is diminished and the temperature is maintained at 37° C. Such difficulty of cultivation is responsible for many errors of diagnosis. This type of actinomycosis was first described by Wolff and Israël and is known as *Actinomyces bovis* (Wolff-Israël).

Rarer type

Although no age is exempt, actinomycosis is seldom found in children under ten years of age; it attacks mainly young people between the ages of fifteen and thirty-five years. Adequate explanation has not been given for the curious fact that males are twice as often affected as females. The disease is responsible for the "lumpy jaw" of cattle, and horses and pigs are occasionally subject to the affection. It is very doubtful whether the disease is ever transmitted from cattle to man, and only two or three possible cases of contagion from one human being to another have been recorded. The so-called "wooden tongue" of cattle is not caused by actinomyces but by a specific bacillus.

Age

Sex

3. MORBID ANATOMY

Actinomyces bovis is a common resident of the mouth in carious teeth and in tartar and the disease frequently originates from portions of the fungus which have escaped into the parts adjoining the alimentary tract, either through a small abrasion of the buccal mucosa, or by taking advantage of openings which may be furnished, for instance, by a perforation of the appendix or of a gastric or duodenal ulcer. It is characteristic that when once the pathological process has begun, the route by which the fungus has escaped closes up and leaves little or no trace. Other methods of infection are by the inspiration of particles of fungus into the air passages and alveoli of the lung and by direct inoculation of the skin. Both cutaneous and pulmonary lesions may sometimes be due to an aerobic form of actinomyces.

Origin of lesion

4. TYPES OF LESION

Actinomycosis can develop in almost any part of the body but grows best in connective tissues. The organism causes a granulomatous reaction in the parts around it. This reaction may be acute and may closely resemble a septic infection; in these lesions pus may soon form and will be found to contain plenty of hyphae without any "granules". In the majority of cases the tissue reaction is subacute or chronic and leads to the formation of a mass of dense fibrous tissue in which the fungus cannot easily be detected by the naked eye or by the microscope. Sooner or later softening occurs and the resulting abscess shows gelatinous pus containing portions of the fungus in the form of small granules which may be coloured yellow, grey or even black; the yellow granules are known as "sulphur grains" and quite often give the first intimation to the surgeon that he is dealing with a case of actinomycosis. The disease usually spreads by local extension. Occasionally lymph nodes are the site of the disease but the rarity of this shows that the lymphatic system is not a common route of extension. Very rarely metastasis by the blood-stream may cause widespread dissemination of the disease. The liver is sometimes infected from an intestinal lesion via the portal system.

Acute reaction

Subacute or chronic type

"Sulphur grains"

Metastasis

Microscopical section

A microscopical section of an actinomycotic lesion shows a mass of tangled Gram-positive mycelium with a border of Gram-negative clubs, which probably represent portions of the fungus which have been altered by the surrounding defensive tissue reaction. Around the mycelium there is a zone of leucocytes, then one of histiocytes, and at the periphery one containing fibroblasts and well-formed fibrous tissue. Many sections may need to be examined before a portion of the fungus is found.

Culture

If culture of the organism is attempted it is essential that the material provided should be fresh, and it should not be allowed to perish by exposure to cold or by drying. Cultivation should be carried out by both aerobic and anaerobic methods. A small coccus, or cocco-bacillus, known as *Bacillus actinomycetum comitans*, is frequently found in the granules of the fungus; its significance is unknown.

Bacillus actinomycetum comitans

5. CLINICAL PICTURE

Common sites

The clinical picture of actinomycosis varies greatly according to the part of the body attacked, the local reaction of the tissues and the stage of the disease. That the origin of the infection is in the alimentary tract is borne out by the fact that 55 per cent of cases occur in the parts adjacent to the mouth and pharynx (cervico-facial type), and another 20 per cent in the appendicular region of the abdominal cavity. In 20 per cent of cases the thorax is involved, and the remaining 5 per cent occur in the skin and other parts of the body.

(1) Cervico-facial type

Dental disease

The common facial type begins, often after the eruption or extraction of a tooth, as a firm swelling in the parotid region or behind the angle of the mandible. The swelling is usually smooth and painless but sometimes there is severe initial pain. The mouth cannot be fully opened. There is rarely any swelling on the medial aspect of the mandible. After a few weeks softening takes place, commonly over the angle of the jaw, more rarely below the orbit; from the pus which escapes the typical granules may be obtained. The primary swelling then subsides, the sinus closes and soon another focus of the disease is detected lower down the neck. This in turn discharges or calls for incision; it closes up after the pus has been evacuated. After some months the series of puckered scars is typical of the picture seen in many

Method of spread



FIG. 19.—Bilateral facial actinomycosis. Dr. G. A. Borthwick's case. (*Reproduced by courtesy of Sir W. Allen Daley.*)

text-books and represents a late stage of the process. The early smooth swelling of the side of the face is seldom correctly diagnosed. (*See* Figs. 19, 20, 21.)



FIG. 20.—Bilateral facial actinomycosis. Dr. G. A. Borthwick's case. (*Reproduced by courtesy of Sir W. Allen Daley.*)

Lower jaw

Occasionally the mandible may be the primary site of the disease. The fungus may enter the cancellous tissue through a tooth-socket, or it may erode the bone from without. A chronic abscess may form in the bone, but more commonly a chronic osteomyelitis is set up and ends in the formation of much soft bone traversed by numerous channels in which the fungus persists and continues its irritation. This type resembles the common form seen in the jaws of cattle. Rarely an actinomycotic nodule forms in the tongue but presents no characteristic picture until the granules are found in the discharge.

Tongue



FIG. 21.—Cervico-facial type of actinomycosis.

(2) Abdominal actinomycosis

Abdominal actinomycosis occurs in most cases in the ileocaecal region and generally supervenes on an attack of perforative appendicitis. The usual story is that after appendicectomy and drainage the resulting sinus fails to heal and its wall becomes indurated. A hard mass may be felt in the right iliac fossa and the observer may note small granules of the fungus in the discharge from the sinus. In other cases the history of appendicitis will not be so clear: the patient may have an attack of right iliac pain of which little notice has been taken and may come to the doctor on account of pain in the right thigh, flexion at the right hip or a lump on the right side of the abdomen. From the iliac fossa the pathological process may spread into

Appendicitis

Microscopical section

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Method of spread

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Tongue

Rarely an actinomycotic nodule forms in the tongue but presents no characteristic picture until the granules are found in the discharge.



FIG. 20.—Bilateral facial actinomycosis. Dr. G. A. Borthwick's case. (*Reproduced by courtesy of Sir W. Allen Daley.*)

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FIG. 21.—Cervico-facial type of actinomycosis.

Spread to spinal canal

the psoas sheath and erode the vertebral bodies and even enter the spinal canal. It is likely that most cases of pelvic actinomycosis (tubal, ovarian) are due to transperitoneal infection from an ileo-caecal lesion. Several cases have been recorded in which an actinomycotic mass (actinomycoma) has formed in the wall of and just external to a portion of the transverse or pelvic colon; such tumour masses are commonly mistaken for cancer.

Liver

Actinomycosis of the liver leads to enlargement of the organ which sometimes presents an irregular surface and may become attached to the anterior abdominal wall. The primary focus from which the disease reached the liver may have disappeared by the time the liver is involved. Irregular fever is commonly present.

(3) Actinomycosis of thorax

Primary infection of lung

The clinical picture presented by actinomycosis of the thorax depends upon whether the lung and pleura or the mediastinum is primarily affected. When the lung is attacked first, consolidation of the middle or lower part takes place, and either an empyema forms or adhesion of the lung to the chest wall occurs and an abscess generally bursts through an intercostal space, usually on a level with the attachment of the diaphragm.

Mediastinum

When the mediastinum sustains the primary attack the disease may be limited to the extrapleural tissues and may come to the surface through the posterior part of one of the intercostal spaces. The thoracic vertebral bodies may be eroded. The penetration of the chest wall distinguishes the lesion of actinomycosis from that of tuberculosis.

(4) Skin, nervous system, breast

Skin

When the skin is primarily affected the disease takes the form of a raised mass of soft granulation-tissue covered by thin epithelium, and showing several discharging sinuses from which the granules may be obtained.

Meningitis

The central nervous system is sometimes secondarily affected from a focus near by. Many cases of meningitis within the skull or spinal column have been recorded.

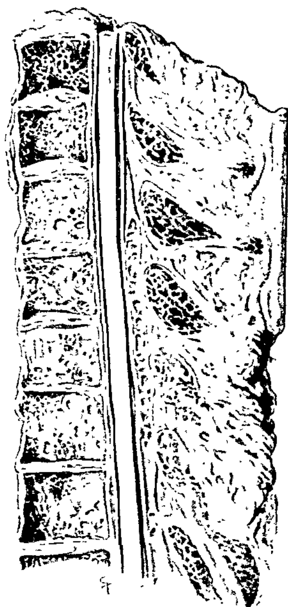
Infection through nipple

A dozen or more cases of primary actinomycosis of the breast are on record and are chiefly interesting because of the likelihood of infection gaining access through the nipple. Clinically the picture is that of chronic abscess with sinus formation.

6. SPECIAL AIDS TO DIAGNOSIS

Diagnosis of actinomycosis is rarely made early, for the finding of the fungus, upon which diagnosis depends, is often delayed for weeks or months after the beginning of the disease. Probably there is not any disease so often wrongly diagnosed by competent observers. The only safe plan is to add actinomycosis to the list of chronic infections which must always be considered in the diagnosis of a doubtful lesion, to make a point of staining and examining under the microscope the pus from every abscess opened and to ensure that a microscopical examination is made of every doubtful tumour removed from the body. Frequently a casual inspection of the pus reveals the characteristic yellow granules of the fungus; their detection may be easier if a little of the pus is shaken up in a test-tube of water, or merely rolled down the side of a

Inspection of pus



Thoracic actinomycosis invading the vertebral column. (*Reproduced by courtesy of Professor W. D. Newcomb.*)

PLATE I

sloping glass vessel. It is not sufficient to detect portions of mycelium in the pus, for small bits of saprophytic hyphae may easily be mistaken for the pathogenic variety. If the fungus is not the predominating organism in the pus it is necessary to cultivate it. The common pathogenic fungus is delicate and is grown with difficulty. Actinomycosis rarely causes an ulcer. Hyphae found in an ulcer with a wide base are almost always saprophytic.

Fibrous type

In the diagnosis of the fibrous type of lesion the fungus must be found and demonstrated in material removed at operation. It may be necessary to examine many sections before any of the fungus is found. The records show that in certain cases the fungus has not been found and because of this its absence has been assumed; an erroneous diagnosis of sarcoma has thus often been made.

7. DIFFERENTIAL DIAGNOSIS

Actinomycosis is protean in its manifestations and is commonly mistaken for other forms of chronic inflammation and for neoplastic conditions. Syphilitic lesions progress more quickly, tuberculous conditions more slowly, and both in contrast to actinomycosis commonly form ulcers. A microscopical examination may be required to distinguish the fibrous tissue reaction of actinomycosis from cancer or sarcoma.

(1) Cervico-facial lesion

The common type which forms a swelling of the face near the angle of the mandible may be mistaken for septic inflammation of the cellular tissues or even for parotitis; incidentally it should be borne in mind that occasionally actinomycosis primarily affects the parotid. As a rule the area involved does not correspond with the outline of the parotid, and the process is not sufficiently acute to be one of sepsis. The condition may coincide with and be taken to be due to an unerupted wisdom tooth. Provisional diagnosis of sarcoma may be made when softening of the fibrous mass is delayed or when the bone itself is the seat of disease. Diagnosis becomes clear only when pus containing the mycelium is obtained or when a typical microscopical picture of the fungus is given.

Tongue

An actinomycotic nodule of the tongue is likely to be mistaken for cancer until the organism is found in the discharge.

(2) Thoracic actinomycosis

This condition is most frequently mistaken for pulmonary tuberculosis, more rarely for growth in the lung. The tubercle bacillus as a rule attacks the apices of the lungs, whereas the actinomyces more commonly affects the lower lobes, and in contradistinction to the behaviour of tuberculous lesions, sooner or later bursts through an intercostal space to form a superficial abscess, from which the fungus may be obtained. In some cases malignant disease of the mediastinum may be simulated. X-ray appearances are not characteristic and diagnosis is usually made late either by finding the fungus in pus coughed up or from an abscess. (*See* Figs. 22, 23, 24.)

Abscess formation

X-ray appearances

(3) Ileo-caecal actinomycosis

When it develops in the ileo-caecal region actinomycosis forms a hard mass which is likely to be diagnosed as malignant disease unless it has supervened

on the removal of a perforated appendix. The induration round the sinus after drainage has been carried out may lead one to surmise that an abscess is forming, but the wooden hardness is usually characteristic and should lead to a careful search being made for granules of the fungus.

(4) Actinomycosis of liver

Actinomycosis of the liver may need to be distinguished from gumma or from chronic pylephlebitis of septic origin. Diagnosis can hardly be made without abdominal exploration and examination of material removed. If, however, actinomycosis has been found in another part of the abdomen and the liver be found much enlarged (either clinically or by x-rays), one should regard hepatic actinomycosis as a likely cause of the enlargement.

(5) Actinomycosis of skin

Actinomycosis of the skin and subcutaneous tissues should be diagnosed early, for it can be readily differentiated from sepsis, tuberculosis and syphilis by the detection of the fungus in the discharge. If the lesion is an open ulcer it is unlikely to be due to the ray fungus.

8. PROGNOSIS

Skin

Recovery is the rule in nearly every case of cutaneous actinomycosis. The rare exception is provided by those cases of cutaneous actinomycosis in which there has been dissemination by the blood-stream, with a fatal result.

Cervico-facial cases

About 97 per cent of the patients with cervico-facial lesions get well.

Abdominal cases

In abdominal cases there is something less than an even chance of recovery, although one must take encouragement from the fact that in seemingly desperate cases patients have been known to recover.

Thorax

Thoracic cases present the worst prognosis but even here there are records of cure.

Relapses

In every type of actinomycosis cure is only achieved slowly and the disease may remain latent for many months only to break out again. Recovery is seldom complete under a period of several months and the disease may persist for a year or more.

9. TREATMENT

There is no specific cure for actinomycosis. Treatment demands a combination of measures which may be described under five main headings: Drugs, Radiation therapy, Vaccine therapy, Constitutional measures and Surgical operations.

(1) Drugs

Potassium iodide

The drug most commonly given is potassium iodide, the dose varying from 10 grains three times a day up to amounts which may reach a total of from 300 to 500 grains daily. These large doses are not justified and are wasteful. The drug, although a specific for the actinobacillosis of cattle, is not specific for mycelial actinomycosis. It is beneficial but not more so than many other forms or preparations of iodine. The simplest and best method of prescribing iodine is in the form of the tincture given in milk (Chitty). Five minims of liquor of iodine in half a tumblerful of milk thrice daily should suffice although larger doses may be given if desired. Colloidal

Chitty's method

iodine may be given by mouth or in severe cases may be injected intravenously in doses of from 10 to 30 cubic centimetres. Injections of Tiodine (a compound of sulphur and iodine) may be given subcutaneously with benefit.

Tiodine

Treatment by drugs of the sulphanilamide group has recently been tried with varying results but on the whole with benefit. There is not any evidence that they have a specific effect but they may help chiefly by diminishing secondary infection. Sulphanilamide itself has been prescribed in doses given at varying intervals, but the total amount given in twenty-four hours has usually been about 4 grammes. Sulphapyridine has also been tried in similar doses and its administration has been followed by great improvement. During the giving of sulphonamide preparations blood counts should be taken every few days so that any tendency towards agranulocytosis may be detected at an early stage; in any case it is wise to have intermissions in the use of the drug so that it is not given for more than a week or two at a time.

Chemotherapy

The local injection of various drugs into the actinomycotic lesion has been recommended by some. Solutions of silver nitrate, copper sulphate and dilute formalin have each had their advocates but the results do not justify their trial.

Local injection

(2) Penicillin

The most recent advance in the treatment of actinomycosis has resulted from the fact that the Actinomyces is sensitive to penicillin though different strains vary in their sensitivity. It has been found that serious lesions, even of the thorax and abdomen will react favourably to treatment by penicillin if the drug be given in sufficiently large doses for a considerable period. Doses of up to half a million units daily should be used, and continued in cervicofacial lesions for two to three weeks, but in thoracic and abdominal lesions it may be necessary to administer this dose for two or three months continuously. When the patient is confined to bed there are many ways of giving the dosage required; it may be given by a slow intravenous or intramuscular drip injection of a solution of the drug in saline or glucose solution, or by repeated (3-hourly) injections intramuscularly. The latter method may be employed for ambulant patients also. A large dose may be concentrated into a small bulk. It is essential that the level of blood-penicillin should be maintained sufficiently high to have a continuous beneficial effect.

We would stress the fact that in treatment of visceral actinomycosis the drug must be administered for a long period without any intermission. Improvement soon takes place, but recurrence is the rule unless the treatment is continued for a long time after all the major symptoms have subsided.

(3) Radiation therapy

There is no doubt that treatment by x-rays is valuable. Whether the rays have a direct action on the fungus is open to doubt, but their application often leads to a rapid softening and improvement in the lesion. Only experts should give the treatment and they differ with regard to the best method of application. Fried recommends a third of an erythema dose given once or twice weekly using 140 kilovolts, 5 milliamperes, filter 4 millimetres

Fried's method

Menninger's method

aluminium. Menninger prefers a 100 per cent dose given uniformly throughout the affected area, using Holdfelder's applicators and cross-fire technique with from 180 to 220 kilovolts, 5 milliamperes, and 0·5 millimetre copper filter. Still others prefer many smaller doses given on successive days to the larger doses given at longer intervals. The surgeon would be wise to leave the dosage to the judgment of the expert whom he may consult.



FIG. 22.—X-ray picture of thoracic actinomycosis to show progress of cure. Treatment was by incision and x-rays. First stage. (*Reproduced by courtesy of Dr. Maurice Davidson and Mr. J. E. H. Roberts.*)

(4) Radium

Method of application

Radium has been used with success in the treatment of actinomycosis. The element itself, radium bromide or seeds containing *the emanation may be* used, and application may be by either local or interstitial method or by the use of the distant bomb. Heyerdahl used radium bromide in platinum tubes containing 1, 2 or 5 centigrams, or in applicators containing 1 centigram. He gave two or three treatments at intervals of six weeks. His actual dosage varied in different cases from that of 6 centigrams for two hours up to that of 11 centigrams for twenty hours, depending upon the type of case. Clearly the dose must be to a certain extent *empirical*, and the surgeon should not carry out such treatment without consultation with an expert worker in radium. In cases of thoracic actinomycosis x-rays and radium have a special use in conjunction with surgical measures.

(5) Vaccine therapy

Vaccines form a useful accessory method of treatment although they do not have a very striking effect. There are three types of vaccine which may be utilized.

Colebrook's method

(1) The method of Colebrook is to break up a culture of the mycelium in saline and to estimate the strength by counting the fragments of mycelium in a given volume. In beginning treatment a good dose would consist of about 2,000,000 fragments, but the amount may be increased up to four or five times this dose. The injections are given at intervals of five days.

Neuber's vaccine

(2) A vaccine is prepared by washing off a maltose agar culture with 5 cubic centimetres of sterile normal saline, triturating the suspension for

fifteen minutes and then filtering. Dosage is started with 0·1 cubic centimetre and is gradually increased to as much as 0·9 cubic centimetre (Neuber).

(3) Particularly in South America, a preparation called actinomycine is largely used. Actinomycine is the filtrate of a culture grown in glycerinated broth and filtered through a Berkefeld apparatus. The treatment is started by using this filtrate diluted to 1 in 100,000. As a preliminary, half a cubic centimetre is injected subcutaneously to test the patient's reaction. If this small dose is tolerated well the dose is increased rapidly until several cubic centimetres of the diluted vaccine may be given twice weekly. Sometimes even the undiluted vaccine may be used in small doses. It is interesting to recall that many years ago Billroth successfully treated a case of actinomycosis by giving large doses of Koch's original tuberculin.

Actinomycine



FIG. 23.—X-ray picture of thoracic actinomycosis to show progress of cure. Treatment was by incision and x-rays. Second stage. (*Reproduced by courtesy of Dr. Maurice Davidson and Mr. J. E. H. Roberts.*)

(6) Constitutional treatment

A patient with actinomycosis is often anaemic and in need of general and tonic treatment. In severe cases, particularly those in which the patients have thoracic and abdominal lesions, it is necessary to treat according to sanatorium methods by rest in bed, the giving of extra milk, and the provision of graduated sunlight, natural or artificial. Anaemia should be treated with iron or liver extract; in severe cases blood transfusion is generally necessary.

Sanatorium routine

10. INDICATIONS FOR SURGICAL INTERVENTION

Surgical operations comprise the opening of abscesses, the excision of parts of a lesion for diagnostic purposes or in order to expedite healing and the total excision of certain types of lesion which lend themselves to this form of treatment.

(1) Cervico-facial cases

When only the soft parts are involved surgery is usually limited to the opening of abscesses. In these rare cases in which lymph nodes are affected it would be wise to excise them, but there is not one case known to the writer in which

such glands were diagnosed as actinomycotic before excision. When the lower jaw is the site of disease it may be necessary to remove a sequestrum, to open a central abscess or to excise large parts of the newly formed soft bone which shows no sign of spontaneous resolution. It is wise to leave the inner table of the bone if possible.



FIG. 24.—X-ray picture of thoracic actinomycosis to show progress of cure. Treatment was by incision and x-rays. Third stage. (*Reproduced by courtesy of Dr. Maurice Davidson and Mr. J. E. H. Roberts.*)

(2) Abdominal actinomycosis

It is usually impossible to excise the whole of an ileocaecal mass; surgery is limited to opening abscesses. Some surgeons advocate the thorough opening up of the sinus in its whole length, but this is sometimes too drastic a procedure. When the lesion is confined to the transverse or pelvic colon it has sometimes been possible successfully to remove the whole affected part, although as a rule this has been done because of a mistaken diagnosis of cancer. Excision of affected ovaries and Fallopian tubes is to be recommended when possible.

In the colon

Ovaries and uterine tubes

(3) Thoracic lesions

Pulmonary lesions

In addition to opening empyemas and superficial abscesses the surgeon may need to resect ribs so as to drain the posterior mediastinum. When the lung is affected the outlook is poor, but cures have resulted either by a combination of incision and radiation or by removing the diseased tissue in stages. Several operations are generally required to get rid of any large focus, for too much must not be done at any one attempt. The tissue is removed by the diathermy knife, and since bleeding is often profuse, blood transfusion may be required. Between operations radium may be applied to the depth of the wound and other measures undertaken, for example the giving of liquor of iodine and the adoption of general tonic measures. It is likely that the need for excision of actinomycotic lung may in the future be avoided by the use of penicillin given in large doses.

Blood transfusion

(4) Cutaneous lesions

Skin grafting

Cutaneous lesions can usually be excised or scraped away, and any resulting granulating surface may be dealt with at a later date by skin grafting.

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ADHESIONS AND CICATRICIAL STENOSES

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1. DEFINITION

9.] This article is limited to peritoneal adhesions and to cicatricial stenoses of the stomach and intestine.

2. AETIOLOGY

Adhesions leading to deformities of the peritoneal cavity may be present at birth, may be the result of inflammation, may follow neoplasms or may be the result of operative intervention. A sound knowledge of the normal variations of the peritoneal cavity is essential if the surgeon is to recognize abnormalities, and this knowledge will be obtained only by a careful study of dissections, horizontal, coronal and sagittal sections and the living pathology demonstrated at operations.

Heredity

Hereditary influence on peritoneal anatomy is a possibility and may explain the frequency of familial incidence, assuming that many cases of appendicitis are due to kinking of the lumen by the peritoneal arrangement. In a family of four all required appendicectomy and a case has been reported in Eire where seventeen out of a family of eighteen suffered from appendicitis. If it is true that a kinked appendix can be handed down from generation to generation we have an explanation for the increase in appendicitis; by saving their lives, the surgeon is flooding the world with appendicular kink-bearers.

Stenoses may be congenital, the sequelae of ulceration due to granulomas, or the result of diverticulitis.

3. ANATOMY

The following are the divisions of the peritoneal cavity.

(a) Subphrenic: right anterior intraperitoneal; right posterior intraperitoneal; left anterior intraperitoneal; lesser sac. (b) Ilio-lumbar: right; left. (c) Pelvic.

Adhesions

Normally there is free communication between all these spaces, but if adhesions develop a portion of the cavity may be shut off. For example a perforation of the gall-bladder or duodenum may isolate the right posterior intraperitoneal subphrenic space by adhesions between the omentum, colon, liver and anterior abdominal wall, or an abscess developing in the



Fig. 25.—Female, aged 35 years. Parieto-caecal fold at the level of the anterior superior iliac spine. Note the small fold attaching the medial aspect of the hepatic flexure to the posterior abdominal wall.

right anterior intraperitoneal subphrenic space will rapidly become confined by adhesions between the omentum, colon, liver and anterior abdominal wall.

In rare cases a complete subdivision of the lesser sac by an adhesion between the lesser curve of the stomach and the pancreas has been seen. This may lead to some confusion during the operation of partial gastrectomy.

Parieto-colic folds

The most constant of the parieto-colic folds attaches the splenic flexure to the diaphragm in the region of the tenth rib and often forms a support for the spleen. On the right side the folds are not so constant and are more variable in size and position. The extensive folds usually form the anterior wall of a fossa.

The following abnormalities may be present in the peritoneum:

Peritoneal abnormalities

(a) The first part of the transverse colon may be adherent to the ascending colon producing a kink at the hepatic flexure.

(b) A portion of the transverse colon may form a U-shaped loop, the two limbs of the loop being closely united.

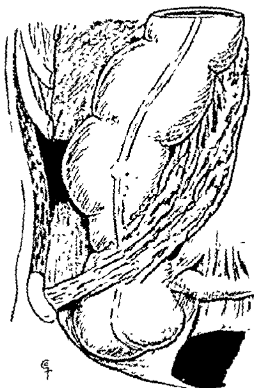


FIG. 26.—Female, aged 58 years. A parieto-caecal fold, formed by the great omentum, has attached itself to the caecum and iliac crest.

(c) The apex of a U-shaped loop of the transverse colon may be fixed to the hepatic flexure, a triple-barrelled arrangement being thus formed.

(d) The transverse colon may be fixed in a position anterior to the liver.

(e) The distal third or fourth of the transverse colon may be fixed by a short fold to the left iliac fossa and posterior abdominal wall medial to the descending colon. This abnormal arrangement of the colon prevents the small intestine entering the left ilio-lumbar region and forces it to take up a position in front of the caecum and ascending colon.

(f) The pelvic colon may form a U-shaped loop which is closely adherent to the iliac colon. This forms a triple-barrelled arrangement of colon.

(g) The transverse colon may pass below the root of the mesentery and behind the coils of the small intestine. It is closely adherent to the posterior abdominal wall.

(h) A short or absent transverse mesocolon.

(i) Absence of the gastrocolic ligament. The great sac passes behind the stomach and the lesser curve of the stomach is *adherent to the pancreas* and diaphragm.

(j) A complete septum bursarum separating the lesser sac into upper and lower compartments.

(k) A paraduodenal fossa may be found to the left of the pars ascendens duodeni with its mouth opening downwards and to the right. Its anterior wall is continuous with the transverse mesocolon. In one recent case the fossa contained almost all the jejuno-ileum. The alimentary canal appeared to have functioned normally, *and the patient died of a* ruptured urinary bladder following an attempted abortion.



FIG. 27.—Female, aged 54 years. Extensive parietocaecal fold, attached laterally to the iliac crest and to the lateral third of Poupart's ligament, and medially to the anterior caecal taenia. Two lateral paracaecal fossae lie behind the fold, one opening superiorly and one inferiorly.

4. MORBID ANATOMY: ADHESIONS

The initial cause of the adhesion may be a wound, appendicitis, perforation of a hollow viscus, mesenteric adenitis, peritonitis (tuberculous, pneumococcal, streptococcal or gonococcal). The peritoneal deformities take the form of close adhesions, cords or bands, and omental fixation.

(1) Close adhesions

It is possible to have all the coils of small bowel fused into a solid mass. Adhesions may be limited to an operation scar or to an area of infection.

(2) Cords or bands

These are produced by an adhesion becoming stretched. They are apt to produce acute small-bowel obstruction by a loop becoming caught.

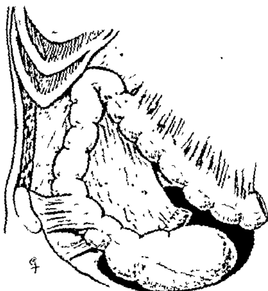
(3) Omental fixation

This is common around the appendix region or in the pelv
to the pelvis it may lead to gastric retention.



FIG. 28.—Female, aged 50 years. Ptosis of the caecum and colon. Extensive sustentaculum hepatis, and a parieto-caecal fold which *appears to be supporting* the caecum.

FIG. 29.—Female, aged 76 years. Marked ptosis of the caecum. Two parieto-colic folds are present: an upper one extending between the iliac crest and the anterior taenia of the ascending colon, and a lower one extending between Poupart's ligament and the postero-lateral taenia of the ascending colon.



(4) Cicatricial stenosis of the stomach

The healing of a gastric ulcer often produces an hour-glass stomach, situated usually in the middle third of the viscus and due to a deposit of fibrous tissue. The fibrous contraction may be accentuated by muscle spasm. (*See* Fig. 37.)

(5) Cicatricial stenosis of the duodenum

At birth the duodenum may be partially obstructed by a perforated septum or completely blocked by a fibrous cord replacing the lumen. Only in the former is life possible. An ulcer may lead to fibrous contraction of any part of the duodenum proximal to the bile papilla.

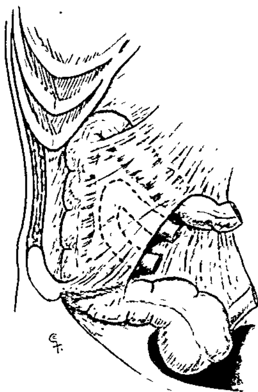


Fig. 30.—Female, aged 67 years. Medial paracolic fossa, containing a loop of small intestine. Adhesion between the colon and the anterior abdominal wall. Ptosis of the caecum.

(6) Cicatricial stenosis of the small intestine

Fibrous strictures of the small bowel, which are usually multiple, follow tuberculous ulceration.

(7) Cicatricial stenosis of the large intestine

Fibrous stricture may follow any of the granulomata (tuberculosis, non-specific infective granuloma, actinomycosis, syphilis) or diverticulitis.

5. CLINICAL PICTURE

Diagnosis Peritoneal adhesions may produce neither signs nor symptoms and their existence may be recognized only at operation or necropsy. In some cases they give rise to abdominal pain suggesting appendicitis or cholecystitis. Attacks of nausea or vomiting are possible. In one case in which all the coils of small bowel were glued together into a mass the only complaint was a bad taste in the mouth.

Signs When acute obstruction develops one finds pain, tenderness and vomiting followed later by distension and a ladder-like abdomen. Adhesions are on occasions palpable, and it has been possible to palpate a mass of omentum wrapped round the stump of an appendix.

Symptoms Patients suffering from cicatricial stenosis give a long history of pain,

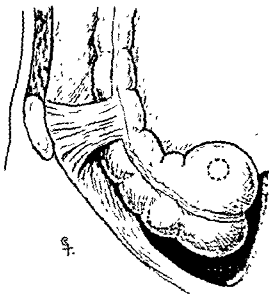


FIG. 31.—Marked ptosis of the caecum and ascending colon. The caecum lies in the true pelvis, and there is an extensive parieto-colic fold in the region of the iliac crest.

vomiting, loss of weight or emaciation and a tendency to constipation. The stomach may be enlarged and show visible peristalsis. Not only does this accompany an obstruction in the stomach or duodenum but it has been seen with a stricture of the ascending colon. This is an important point since a gastro-enterostomy will not help a stricture of the ascending colon.

A colonic stricture may cause the large bowel to stand out visibly at times, and a peculiar point about this type is that the colon distal to the stricture may be almost as much distended as the proximal portion. This may be due to antiperistalsis or to the pressure of enemas.

6. SPECIAL AIDS TO DIAGNOSIS

adiology

Normally a meal has left the stomach and small intestine seven hours after ingestion. The presence of a quantity of the meal in the small bowel seven hours after ingestion should make one suspect a small-bowel obstruction.

The presence of calcareous mesenteric glands as revealed in a skiagram and accompanied by colic should make one consider the possibility of adhesions.

Adhesions of the gall-bladder may be demonstrated by cholecystography. In a recent case the gall-bladder was outlined as a U-shaped opacity, the fundus being directed upwards and outwards. This was confirmed at operation.

The opaque enema, if normal, excludes the presence of colonic obstruction or dolichocolon. It may show obstruction to the passage of the enema and in rare cases this obstruction may be due to adhesions. In one case the enema did not pass beyond the pelvic colon, and at operation a peritoneal band was found attaching closely the two ends of the pelvic colon. Division of this band and separation of the ends of the bowel relieved the obstruction.

7. SPECIAL AIDS TO DIAGNOSIS IN CICATRICIAL STENOSES

(1) Straight skiagram

A skiagram of the abdomen without the introduction of any opaque substance may show calcareous glands or an abnormal collection of gas in the colon. The normal abdomen shows gas bubbles at the hepatic and splenic flexures, a gas bubble in the fundus of the stomach and a small but variable

amount in the pelvic colon. With obstruction to the outflow from the stomach the gastric bubble will be enlarged. In colonic obstruction there will be an abnormal accumulation of gas proximal to and terminating at the stricture.

(2) Opaque meal

Seven hours after ingestion an opaque meal should occupy the right colon. The presence of an opaque meal in the stomach at this time suggests obstruction due either to pyloric spasm or to an organic obstruction in the alimentary canal. It is a valuable guide to the surgical abdomen, but it may require an operation to disclose the seat of the lesion which may be anywhere from the stomach to the right colon.

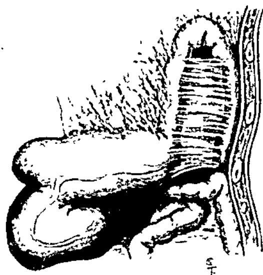


FIG. 32.—Abdominal viscera of a male subject, aged 64 years, viewed from the left side. Portions of small and large intestine are exposed. The terminal five inches of the transverse colon are attached to the posterior abdominal wall by a peritoneal fold. The transverse colon proximal to this fixed portion is loaded with faeces. This abnormal attachment of the transverse colon has produced a kink at the splenic flexure, and has also prevented the small bowel from entering the upper part of the left iliolumbar region.

The seven-hour picture is also of value in disclosing a stricture of the ascending colon or the filling defect of a granuloma of the caecum or ascending colon.

The immediate opaque meal picture may show an hour-glass stomach or an hour-glass duodenum.

(3) Opaque enema

A thirty-ounce opaque enema should outline the entire colon. This test is of special value in obstructions of the left colon: the head of the enema will indicate the site of obstruction. The different varieties of dolichocolon and the presence of diverticula may be recognized.

8. DIFFERENTIAL DIAGNOSIS IN ADHESIONS

(1) Appendicitis
(2) Cholecystitis
(3) Constipation
(4) Mesenteric adenitis
(5) Renal colic
(6) Dolichocolon
(7) Granuloma
(8) Carcinoma of colon
(9) Volvulus

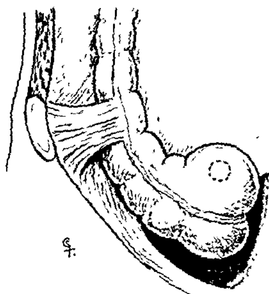


Fig. 31.—Marked ptosis of the caecum and ascending colon. The caecum lies in the true pelvis, and there is an extensive parieto-colic fold in the region of the iliac crest.

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lesion such as disease of the gall-bladder or appendix. Occasionally it is seen in action during exploration, and will appear as a firm white spasm which passes off in ten or fifteen minutes.

(c) *Carcinoma*

The short history, the anaemia and loss of appetite should make one suspect the condition. The development of an ulcer cancer with its long ulcer history may lead to confusion. A two-year cure after a short-circuit operation should rule out carcinoma.

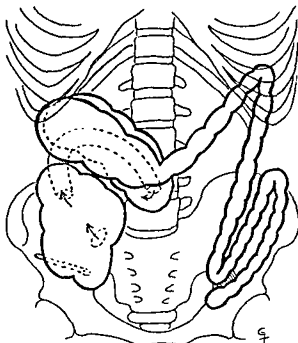


Fig. 34.—Abnormal arrangement of the transverse and pelvic colon. The apex of a loop of transverse colon is fixed to the hepatic flexure, the loop and the proximal few inches of the transverse colon forming a closely united triple-barrelled arrangement. The limbs of a loop-shaped pelvic colon are closely united at the base of the loop.

(2) Duodenum

Diverticula

Diverticula of the duodenum may be congenital or cicatricial. The congenital variety is found on the pancreatic border of the second or third parts, and rarely gives rise to any symptoms, but might be confused on the skiagram with a fibrotic stricture following ulcer of the second part.

The cicatricial variety usually involves the first part and is the result of the cicatricial contraction of an ulcer.

(3) Jejuno-ileum

Adhesions of this part of the alimentary tract must be differentiated from

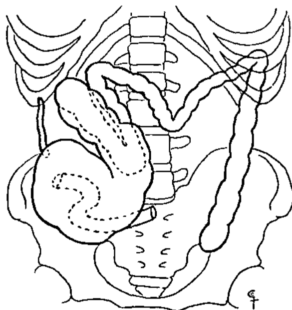


Fig. 35.—Male, aged 63 years. The fundus of the caecum is fixed in a high position by a pre-renal appendix. Kinks are present in the terminal ileum, at the hepatic flexure and in the transverse colon. The first few inches of the transverse colon descend retroperitoneally behind the ascending colon and then turn sharply upwards.

Diagnosis by exclusion

The above list of conditions shows that a large number of abdominal conditions can be confused with adhesions, and it is usually by a process of exclusion that one arrives at the diagnosis. Attacks of pain in the right iliac fossa following removal of the appendix are probably due to adhesions. Obstructions of the colon may be due to abnormal peritoneal arrangement.

Abnormal elongation of a segment of colon is known as dolichocolon which most frequently affects the pelvic colon. It simulates adhesions or carcinoma by giving rise to colic, distension and, more rarely, haemorrhage. The condition is demonstrated by an opaque enema.

Granuloma and carcinoma will present a palpable tumour and a filling defect or obstruction on examination by skiagram.

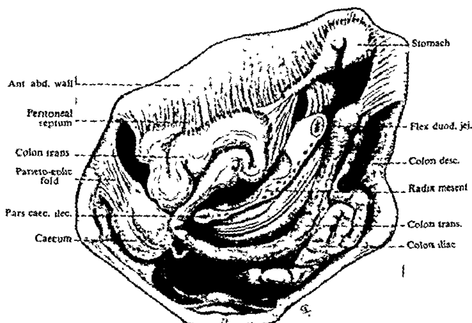


FIG. 33.—Abnormal arrangement of the peritoneum and transverse colon. The transverse colon passed inferior to the root of the mesentery. Throughout its whole course it was closely adherent to the posterior abdominal wall or to viscera lying on the posterior abdominal wall. The left ilio-lumbar region ascended freely behind the stomach, so that there was no retrogastric lesser sac of peritoneum. A peritoneal adhesion, attaching the transverse colon and great curvature of the stomach to the anterior abdominal wall, separated the abdomen into upper and lower compartments.

9. DIFFERENTIAL DIAGNOSIS IN CICATRICIAL STENOSES

(1) Stomach

(*a*) *Hypertrophic stenosis of the pylorus*

Hypertrophy of the musculature of the pyloric canal will give rise to obstruction and a filling defect of the pyloric end of the stomach. The condition will be recognized at operation.

(*b*) *Pyloric spasm*

This may simulate a cicatricial stenosis, and may be due to some distant

seen sufficiently early the division of the cord is all that is required and the cure will be permanent.

Post-operative small-bowel adhesions

The onset of colic and vomiting in the presence of a lower abdominal scar should make one suspect a small-bowel obstruction and adhesions to the back of the scar may be found. The right ilio-lumbar region is the popular hunting ground for the adhesions enthusiast as here are situated the ileal kink, Jackson's membrane and the various parieto-colic folds. It is difficult to see what



FIG. 37.—Male, aged 33 years. Skiagram of stomach after opaque meal, showing a mid-gastric hour-glass contraction, with a large Haudeks niche.

harm a transparent Jackson's membrane could do, but parieto-colic folds, by supporting the ascending colon and caecum, appear to be of value. Some surgeons claim good results by anchoring the ascending colon to the parietal peritoneum.

Ileal kink

An ileal kink, unless it is very marked, is unlikely to obstruct the passage of the fluid contents. Solid bodies, such as peas, are more apt to be held up at the valvula coli. The surgeon should be aware of the possibility of a peritoneal colonic kink giving rise to attacks of abdominal distension, colic and

Peritoneal colonic kink

sarcoma or carcinoma, Meckel's diverticulum, internal hernia, chronic intussusception, regional enteritis and appendicitis. This is the most difficult part of the alimentary canal to examine. Its length, the fluid nature of its contents, the rapidity of transit and the absence of symptoms or signs in the presence of definite morbid anatomy make the diagnosis exceedingly difficult. The surgeon will be fortunate to have the opportunity of discovering a lesion in the absence of acute obstruction. Colic, a palpable lump and a history of blood and diarrhoea, if present, would be useful.



FIG. 36.—Gall-bladder, showing a Hartmann's pouch medial to the cystic duct, and a kink of the cystic duct maintained by ligaments attaching the lateral aspect of the neck of the gall-bladder to the porta hepatis. The gall-bladder was distended and did not contain any stones. There had been attacks of biliary colic, so the gall-bladder was removed.

(4) Colon

Adhesions of the colon must be differentiated from carcinoma, volvulus and dolichocolon.

(a) Stricture

Most colonic strictures are malignant, and it is very rare that a simple stricture, the result of a healed granuloma, is encountered. Most surgeons have performed a colostomy for a tumour of the pelvic colon and have found the patient well ten years later. Such cases are probably examples of diverticulitis.

(b) Dolichocolon

Dolichocolon is an elongation of a segment of the colon and may involve the pelvic, iliac or transverse colon. It simulates stricture by giving rise to attacks of colic, distension, constipation and, more rarely, by the passage of red blood. It is recognized by the opaque enema.

10. INDICATIONS FOR SURGICAL INTERVENTION IN ADHESIONS

(1) Acute obstruction of the small intestine.

(2) Gastric retention following a lower abdominal operation performed some years previously.

(3) A palpable mass in the right iliac fossa with a previous history of appendicitis.

(4) Deformities of the gall-bladder associated with biliary colic and demonstrated by a skiagram.

(5) Well-marked ileal stasis demonstrated by a skiagram and associated with attacks of abdominal pain. This suggests the possibility of an *ileal kink*.

(6) Colonic kinks accompanied by colic and constipation and demonstrated by opaque meal or enema.

Prognosis in band division

The most satisfactory of the above operations is the relief of acute obstruction of the small intestine by a band or cord. If the patient is

(b) Sleeve resection with a posterior gastro-enterostomy into the lower pouch.

This is indicated in a high hour-glass stomach where the technical difficulties of a gastrectomy might be many. If the sleeve resection is not followed by a gastro-enterostomy a gastric retention will result.

(2) Pyloric or duodenal obstruction

A posterior gastro-jejunostomy should be performed.

(3) Stricture of the small intestine

Resection of a portion of bowel and an end-to-end anastomosis.

(4) Stricture of the right colon

A right colectomy.

(5) Stricture of the left colon

A left colectomy.

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[References to other titles are given under Adhesions in the Index Volume.]

constipation. In one patient the condition was relieved by dividing a band which was uniting the proximal and anal ends of the pelvic colon.

Recurrence

Apart from congenital bands and post-inflammatory cords, adhesions show a marked tendency to recur after division and the covering in of raw areas becomes a great problem. In some cases they are covered satisfactorily by utilizing the omentum. Serious adhesions may follow gynaecological operations or the abdomino-perineal excision of the rectum.

11. INDICATIONS FOR SURGICAL INTERVENTION IN CICATRICIAL STENOSES

(1) Hour-glass stomach.
(2) Gastric retention.
(3) Obstruction of the first or second parts of the duodenum.
(4) Obstruction of the small intestine.
(5) Obstruction of the large intestine.

12. OPERATIVE TECHNIQUE IN ADHESIONS

(1) The incision

Where a small-bowel obstruction is suspected a subumbilical midline incision is advised.

The ileo-caecal region can be explored through a paramedian incision.

In the presence of an operation scar it will be safer to open the abdomen medial or lateral to the scar.

(2) Inspection and palpation of contents of abdomen

Blood-stained fluid will suggest strangulation. Distended coils of the small bowel indicate obstruction, and this may be accompanied by collapsed coils below the obstruction. It may be necessary to withdraw several feet of the bowel before the diagnosis can be established. Thickened coils can be palpated and lifted out of the pelvis for inspection.

(3) Technique

This may consist of:

(a) Divisions of adhesions and covering in of the raw area.

(b) Division of an obstructing cord.

(c) Resection of a portion of small intestine followed by an end-to-end anastomosis or by a temporary faecal fistula according to the condition of the patient.

(d) Division of the ileum, closure of the distal end and implantation of the proximal end in the transverse colon. This may be indicated in gross adhesions of the terminal ileum.

13. OPERATIVE TECHNIQUE IN CICATRICIAL STENOSES

(1) Hour-glass stomach

(a) Removal of the lower two-thirds of the stomach including the hour-glass, closure of the duodenum and anastomosis of the stomach to the jejunum by a retrocolic end-to-side gastro-jejunostomy.

of appreciable size are found in these adhesions, and in others the lung cavity may be involved in the visceral end of the adhesion, particularly when the pulmonary attachment is broad.

Criterion of efficiency

It is now well recognized that the clinical efficiency of an artificial pneumothorax is in direct proportion to the degree to which the pulmonary lesions can be collapsed, and therefore any method that will bring this about without undue risk to the patient is justifiable.

The method widely adopted today is that of division of the adhesions by a cautery, either electric or diathermic, used under vision through a thoracoscope.

2. INDICATIONS AND CONTRA-INDICATIONS

The indications are today much wider than those formerly adopted. It has been shown in many published statistical groups of the end-results of artificial pneumothorax therapy that those limited by the presence of adhesions, even when the immediate results of incomplete collapse may be satisfactory, are considerably inferior to those in which collapse is complete. Thus the division of all adhesions where this is safely possible should be undertaken.

More urgent indications for operation are excessive cough, pain and haemoptysis, especially when the first two are provoked by pneumothorax refills.

Obviously, cavities held open by adhesions provide a strong indication, and this is especially the case in the so-called suspended or "hanging" cavity, as this type is more liable to perforate into the pleural cavity and more commonly is associated with bronchogenic spread of the disease.

Criteria of operability

The first criterion of the possibility of operation is the skiagram, which will generally indicate cases in which operation cannot be considered owing to widespread surface adhesions. This should be associated with radioscopy.

Radiological

The radiological examination in other cases will indicate the practical certainty of successful operation, as a cord-like adhesion will be seen holding out a cavity. Many cases, however, lie between these groups, and in these the decision can be determined only after thoracoscopic examination of the pleural cavity and visual examination of the adhesions. By this examination adhesions not visualized by radioscopic or radiographic examination are often seen, but these are generally thin bands or cords the division of which offers no difficulty.

Thoracoscopic

The ultimate criterion of operability is necessarily visualization by the thoracoscope. The adhesions which it is proposed to divide should be clearly seen in their entirety before adequate assessment can be made, and will often require the use of both oblique and right-angled telescopes through both cannulae before this can be satisfactorily accomplished, especially where the broader bands are concerned.

It is often found that what have appeared as multiple bands in the skiagram, or on screening the patient, shows through the thoracoscope as a massive adhesion with thickened ridges.

Obviously, it is essential before thoracoscopy that there should be a sufficient air space between the lung and the chest wall to permit introduction of the trocar and cannula without damage to the lung.

ADHESIONS (PLEURAL) IN PULMONARY TUBERCULOSIS

* By The Late A. TUDOR EDWARDS, M.D., M.Chir., F.R.C.S.
Surgeon, Brompton Hospital, London; Surgeon in Charge, Department of Thoracic Surgery, London Hospital

1. GENERAL

Significance in artificial pneumothorax

10.] The significance of pleural adhesions in the treatment of pulmonary tuberculosis by artificial pneumothorax lies in the fact that they are usually *found over the diseased portions of the lung, particularly over cavities, which* it is the object of the treatment to collapse. Adhesions may be generalized throughout the pleural layers, preventing the induction of any pneumothorax, but it is more common to find that after the induction of a pneumothorax and its continuance by further refills, collapse of the lung is incomplete and the diseased area or areas, generally containing a cavity, is tethered to the chest wall by adhesions between the visceral and parietal pleurae.

Specific objects

One of the chief indications for collapse therapy is the complete closure of pulmonary cavities at the earliest possible moment with two specific objects in view: (a) as a general social measure—to prevent the expectoration of sputum which contains tubercle bacilli and is liable to lead to the infection of others, particularly children, and (b) in the direct interest of the patient—to arrest the disease and prevent "spill-over" or bronchogenic spread of the disease to the same or contralateral lung.

"Contra-selective" collapse

Types of adhesion

In many patients a wide area of the lobe, usually the upper, is adherent to the chest wall, the pneumothorax being chiefly over the unaffected portion of the lung. In these cases the collapse has been termed "contra-selective" and artificial pneumothorax should be abandoned and some other form of collapse therapy substituted. In other patients, instead of surface adhesions being present, radiography may reveal a single string-like adhesion holding open a cavity. Almost every variety of adhesion, single or multiple, between these extremes may be encountered. They may be strap-like, spool-shaped, or of other forms. In the majority the adhesion consists of fibrous tissue which has been pulled out to its shape by the steady negative pressure of the lung which has been permitted to act upon it once the major portions of the pleural surfaces are separated by the air in the artificial pneumothorax. Vessels sometimes

* The untimely death of the author prevented the selection and approval of illustrations for this article. Reference should be made to the article in a later volume on Pulmonary Tuberculosis for illustrative diagrams and X-ray pictures.

give a moderate red heat. When it is too hot, the adhesion is rapidly divided and any contained vessels are likely to bleed. If it is not hot enough, charring of the adhesions occurs associated with the production of smoke which interferes with visualization.

After the adhesion is divided as near the chest wall as possible both stumps should be examined for bleeding. Any small bleeding point may be touched by the cautery and will usually cease bleeding. It is always advisable to divide adhesions on the mediastinal surface before those on the axillary surface, as division of the latter first will result in loss of tension of the more difficult mediastinal bands.

Diathermy

Disadvantages

Diathermy, which is sometimes used for coagulation and subsequent division of adhesions, has been abandoned widely in favour of the electric cautery. The former tends to cause irregular and painful contractions of the intercostal muscles, and therefore requires infiltration of the intercostal space near the costal end of the adhesion with local anaesthetic before the division is made.

Diathermy has the added disadvantage that the division of the narrow adhesions is more difficult and the coagulation tends to spread down towards the pulmonary end.

Enucleation of adhesions

In all except the veil-like and string-like adhesions an enucleation of the band should be done at the costal end. Enucleation is attained by dividing the pleura around the area of attachment of the adhesions to the chest wall. This releases the band and it is gradually separated, occasionally by blunt dissection, from the thoracic parietes, visible thickened strands being divided by the cautery until the band is free and falls away loosely on to the lung. This method will obviously be impossible where the adhesions are attached to large vessels, and in such cases the hook-cautery is invaluable in lifting the band away from the vessel before cauterizing it. Broad adhesions attached to the larger vessels are unsuitable for division.

Bronchial fistula

The partial division of broad adhesions is inadvisable, as tearing of a further portion may occur following cough during the ensuing days or weeks, with resultant infection of the pleura or the development of a bronchial fistula. It is much better practice to divide all other adhesions which are safely divisible so that the pull of the pneumothorax is exerted on the broad adhesion, and to examine the patient by thoracoscopy three to four weeks later.

At the conclusion of operation the cannulae are withdrawn, the skin and subcutaneous tissues sutured, and a firm pad or rubber sponge strapped over the sutured areas. The air pressures in the pneumothorax should then be adjusted to the pre-operative level, and the patient nursed in a position designed to prevent the approximation of the divided ends of the adhesions and their re-formation.

4. COMPLICATIONS

Surgical emphysema

The most common complication, although it is rarely of importance, is surgical emphysema, which always occurs to a limited degree around the incisions. In rare cases it may become more marked, and even result in considerable re-expansion of the lung from escape of air from the pleura. It should be controlled by firm pressure and strapping, and control of cough for twenty-four hours after operation.

3. TECHNIQUE

Advantages of two-cannula method

Operation can be carried out by the two-cannula method or the one-cannula method. The former, although the attainment of the technique is more difficult to acquire, offers many advantages:

(i) It permits more accurate all-round visualization.

(ii) The cauterization can be done through either cannula, thus allowing the electrode to be brought at right angles to adhesions running in various directions.

(iii) The telescope is bigger, permitting better illumination and visualization.

(1) Instruments

The instruments in the double-cannula method consist of (a) two cannulae and trocars; (b) right-angled and fore-oblique thoracoscopes; (c) a series of cauteries, straight, hook-shaped and one which can be rotated almost to a right angle after introduction—all cauteries can be used with the electric or diathermic current as desired; (d) a long fine needle for introduction of local anaesthesia into the pleural end of the adhesion when diathermy is used; (e) a blunt dissector and (f) a suction cannula to remove blood or fluid in the pleura.

In the single-cannula method, the whole procedure is carried out through one cannula, which carries the cautery as well as the telescope.

(2) Two-cannula method

Premedication

The chest wall is prepared as for any surgical operation. The operation is preceded by a subcutaneous injection of Omnopon $\frac{1}{3}$ grain and scopolamine (hyoscine) $\frac{1}{150}$ grain—or less, if considered advisable, in women, given one hour before the time arranged for operation. It is advisable for any operator to use as far as possible the same sites for introduction of the cannulae in all cases, unless local conditions prohibit. In this way his orientation is immediate and the position of vital structures easily determined.

Site of operation

The fifth interspace just in front of the angle of the rib, with the scapula well forward and the patient lying on the opposite side, is a good site for one cannula; the other cannula is well placed about the third or fourth interspace in the mid-axillary line.

Local anaesthesia

Local anaesthetic solution (1 per cent procaine hydrochloride) is infiltrated into the proposed line of insertion until on withdrawal of the piston air appears in the syringe.

(3) Operative procedure

A needle with a flexible stilette, loosely fitting and projecting about an inch beyond the point, is then introduced to determine a sufficiency of free space for the introduction of the trocar and cannula. An incision long enough to permit easy passage is made through the skin and the trocar and cannula are forced through the anaesthetized intercostal space. The trocar is withdrawn and replaced by the telescope and the pleural space examined.

In the absence of adhesions in the axillary line, and if the adhesions appear divisible or require further examination, the second cannula is introduced into the axilla and further telescopic examination made. Before section of the adhesion is begun the current running through the cautery is adjusted to

ADIPOSITY

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1. AETIOLOGY

Types

1.] There are two main types of adiposity: an exogenous type, caused by excessive intake of food, and an endogenous type, produced by disturbance of the mechanism which regulates the metabolism and deposition of fat. The intake of food of most persons is in excess of bodily requirements, and were it not for the weight-regulating mechanism, increasing adiposity would be very common. Some people through gross overeating put undue strain on this mechanism and adiposity is the result. These form a minority. Adiposity occurs commonly in persons who eat no more than do their fellows, and in these the condition is due to a defective weight-regulating mechanism. The exact nature of this mechanism is uncertain.

Exogenous adiposity

Endogenous adiposity

Endogenous adiposity occurs as a symptom of gross endocrine disturbance, as in Fröhlich's syndrome, hypophyseal tumour, Cushing's syndrome, hypothyroidism, the adreno-genital syndrome, eunuchism and eunuchoidism and spontaneous hypoglycaemia; it also may be post-menopausal. The normal storage of fat is thus dependent upon a correct balance of the internal secretions. In the absence of any distinct endocrine disorder, endogenous adiposity is due probably to disturbance of the centres in the hypothalamus which regulate fat metabolism, and not to hypopituitarism, as commonly supposed. It may arise as a sequel to encephalitis or basal meningitis.

2. CLINICAL PICTURE

The clinical features described below are those of adiposity unconnected with any definite endocrine disease. The distribution of the fat is generalized, involving the face, trunk and limbs. The general health is good, but on exertion there may be dyspnoea due to fatty infiltration of the heart. There may be amenorrhoea. Because of the increase in weight, these patients suffer more often from backache, flat-foot and osteoarthritis of the hips and knees than do persons of normal weight. They are also prone to diseases such as hypertension, angina of effort, bronchitis, cholecystitis, gall-stones, diabetes mellitus, gout and umbilical and inguinal herniae.

3. SPECIAL AIDS TO DIAGNOSIS

The usual case of adiposity requires no further investigation than a full clinical examination. In cases in which hypothyroidism is suspected an estimation

Haemorrhage

Haemorrhage of any degree is rare, but may be sufficient to require thoracotomy and diathermy of the bleeding point. A lesser degree of haemorrhage may necessitate blood transfusion and aspiration of the blood in the pleura.

Pleural effusion

Pleural effusion of small extent is relatively common and usually is reabsorbed. When more considerable, the pleural effusion should be aspirated and rarely requires further intervention.

Tuberculous effusion

Secondary infection

In other cases, even up to weeks later, particularly if the lung has been damaged, a tuberculous effusion may result. It will require repeated aspiration and may necessitate abandonment of the pneumothorax. If more extensive damage has been caused to the lung, the effusion may result in a mixed infection resulting from tuberculous and pyogenic organisms with or without a broncho-pleural fistula. In the absence of a fistula, and if the secondary organisms are penicillin sensitive, the severity of the complication can be controlled by aspiration, and instillation into the pleura of 40,000 to 60,000 units of penicillin every 48 hours.

Treatment

This treatment should eliminate the risk of the combined infection and should, if successful, remove the case into the earlier group of tuberculous infection of the pleura.

Broncho-pleural fistula

In the presence of a broncho-pleural fistula intercostal drainage is essential to prevent bronchogenic spread of the combined infection to the opposite lung. It should be associated with penicillin instillation into the pleura in doses of 60,000 units on alternate days.

Intercostal drainage

When carrying out intercostal drainage in these cases, the probability of eventual thoracoplasty must be borne in mind. It is therefore essential to insert the tube in such a position as not to contaminate the eventual thoracoplasty operative field. The tube should be inserted low down in the anterior axillary line or below the tenth rib. The former site has the disadvantage that the pleura will not be drained at its lowest point, and the latter situation is probably better, although it will entail completing the thoracoplasty in stages down to and including the ninth rib and making a separate stage for the tenth rib, so that wide infection of the wound is avoided.

Technique

A trocar and cannula is employed to penetrate the pleura, under local anaesthesia, the trocar withdrawn and a Malecot's catheter, stretched on an introducer, inserted; the cannula is withdrawn, leaving the tube *in situ*. In this way a tube firmly fitting the track is employed, and it should be fixed by a safety-pin and adhesive strapping to the chest wall. The pleural contents having been aspirated, on the patient's return to bed the tube is connected to an under-water drainage bottle for continuous drainage.

Post-operative drainage

In these cases, thoracoplasty is almost invariably required later, if the condition of the contralateral lung permits, and should be considered as soon as the patient has survived the acute stage and the condition has become temporarily stabilized.

[References to other titles are given under Adhesions in the Index Volume.]

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Basal metabolic rate

of the basal metabolic rate may be necessary, but in assessing the result it should be borne in mind that the body surface may be so greatly increased that the figure obtained is likely to be inaccurate.

Skiagram of hypophyseal fossa

When adiposity is accompanied by amenorrhoea or other symptoms which may indicate hypophyseal disease, such as headache, failing vision or lessened potency, an x-ray examination of the hypophyseal fossa should be made in order to exclude a tumour of the pituitary.

Glucose tolerance

It is not unusual to find a low glucose-tolerance curve in patients with adiposity, and the test in the majority of cases has no practical value. A low fasting blood-sugar level will throw light on the rare cases due to spontaneous hypoglycaemia.

4. DIFFERENTIAL DIAGNOSIS

Inquiry into the amount of food and alcohol taken should enable exogenous to be distinguished from endogenous adiposity. There may be no clear dividing line, however, between the two, since the patient with endogenous adiposity may overeat. An exogenous factor having been excluded, the various causes of endogenous adiposity should be considered. In the adiposity associated with hypophyseal disease, the excess of fat is deposited proximally, that is, over the trunk and proximal parts of the limbs, and it may be accompanied by other signs of hypophyseal dysfunction. In Cushing's syndrome and in the closely related adreno-genital syndrome the distribution is also proximal, the onset of adiposity is often rapid and painful, and other features of these conditions—the most noteworthy being masculinization—are present. In hypothyroidism the adiposity is generalized, and often there are pads of fat above the clavicles.

Endocrine diseases

5. PROGNOSIS

The expectation of life is diminished because of the complications to which adipose patients are prone.

6. TREATMENT

Reduction in the intake of food will decrease the storage of fat whether the patient has exogenous or endogenous adiposity. The most important part of treatment, therefore, is the taking of a reducing diet of 1,000 calories a day, in the proportions of 100 grammes of carbohydrate, 60 grammes of protein and 40 grammes of fat. The most important reduction is in the consumption of carbohydrates and of fats. Too great a reduction of fat renders the diet difficult to take and unpalatable and, moreover, is unnecessary. Alcohol and sweetened drinks should be avoided, and since in some cases there may be retention of sodium chloride and of water, salt should be reduced to the minimum.

Reducing diet

Foods to be avoided

Foods which should be avoided are sugar, confections, pastry, cakes, cereals, fried foods, fat meats (such as bacon, pork, goose and duck), potatoes, peas, beans, parsnips, beetroot, sweet puddings, tinned fruits in syrup, bananas, nuts, jam, cream, salad dressings, thick soups and sauces. Saccharine may be used for sweetening. The bulk of carbohydrate allowed should consist of fruit and vegetables, since these have a low calorie value and give bulk to the diet.

Too rapid a loss of weight should not be allowed: it is sufficient if there is a

loss of from two to three pounds weekly. During the period of treatment the patient should be under medical observation; when the desired weight has been reached the diet should be increased, but not so much as to cause a further gain in weight.

Vitamins and calcium

A reducing diet is usually low in vitamins and calcium. For this reason, *when the intake of food is low it is well to prescribe 3 compound vitamin* tablets and 30 grains of calcium lactate to be taken daily.

Extract of thyroid gland

Except in cases in which there is hypothyroidism, administration of preparations of the thyroid gland is rarely necessary. When the reducing diet does not produce a satisfactory response, thyroid extract, given in daily doses of 1 grain—which may be increased or decreased as necessary—often proves to be invaluable. Some cases of adiposity, however, are resistant to the action of thyroid extract. No effect is obtained with other endocrine preparations, with the exception of the testosterone compounds administered in cases of the adiposity associated with hypogonadism.

Physiotherapy

Massage does not reduce weight, although popular belief is to the contrary. Exercise has to be severe and sustained in order to produce any appreciable effect, and has the disadvantages that it increases appetite and that it cannot be carried out by the adipose patient because of his poor physical condition. Turkish baths and purgation cause only transient loss of weight through temporary loss of water, and are not to be recommended.

7. RESULTS OF TREATMENT

Relapse with increase of diet

Most cases of adiposity respond to restriction of food intake with or without the administration of thyroid extract, but gain in weight will occur if the patient returns to former dietetic indiscretions. Usually a modified normal diet may be taken with impunity after reduction has been obtained, but in some patients strict dieting is always necessary to prevent gain in weight. In a few cases even strict dietetic measures and the administration of thyroid extract fail to produce any appreciable reduction in weight.

[References to other titles are given under Adiposity in the Index Volume. The subject of Adiposity is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 202.]

ADRENAL GLANDS

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* The term "basopilism" is sometimes employed. Crooke's hyaline cells are nearly always present in the pituitary with the adrenal syndrome.

1. INTRODUCTION

12.] The adrenal glands are essential to life. Surgical treatment is therefore governed according to whether only one or both adrenal glands are involved. Some lesions of the cortex and medulla give rise to marked endocrine disturbances, but others do not. As a consequence adrenal disease is diagnosed earlier when these effects are present than when they are not.

2. ENDOCRINE EFFECTS OF THE ADRENAL GLANDS

The earliest observation on disease of the adrenal glands was made in 1855 when Addison first described the fatal malady (Addison's disease) characterized by progressive loss of strength and general pigmentation of the skin. For a long time it had been recognized that Addison's disease was due to defective secretion of some adrenal hormone. Later it was found that adrenalectomized animals could be kept alive by perfusion with cortin—an extract of the adrenal cortex. It is now known that these animals can be kept alive by perfusion with salt alone.

Hypo-adrenia

An important function of the adrenal cortex is its effect upon the secondary sex characters. It has long been known that sex changes are associated with adreno-cortical tumours. However, it was not until recently that Vines, by means of the ponceau-fuchsine staining reaction, was able to differentiate between those adreno-cortical tumours which were physiologically active and those which were not.

Functions of cortex

The other important function concerns the medulla, from which Schaefer succeeded in isolating adrenaline. This substance, apart from its vasopressor effect, was subsequently shown by Cannon to provide by its liberation into the blood-stream a rapid mobilization of sugar into the tissues in preparation for immediate action. More recently, it has been shown by Dale that adrenaline plays an important part as a chemical mediator in the transmission of nervous impulses along the sympathetic autonomic system.

Tumours of the adrenal medulla are mainly concerned with the production of hypertensive attacks.

3. DIAGNOSIS OF ADRENAL LESIONS

Before discussing the clinical manifestations of adrenal disease, it is necessary to consider recent advances upon which adrenal surgery is based. It must be realized, however, that the surgeon represents only one unit in a team of combined investigators, each of whom has his special part to play. The following views are the result of such team work at Charing Cross Hospital, London.

There are now two fundamental observations from which surgery of the adrenal gland can proceed—the ponceau-fuchsin staining reactions, and the biochemical determination of androgens.

Fundamental observations

(1) Pathological

The ponceau-fuchsine staining reaction is a differential stain which enables us to distinguish the hyperplasias and tumours of the adrenal cortex which are

Ponceau-fuchsine stain

Technique

physiologically active, from the inactive. The details of the technique are fully described elsewhere (Broster and his colleagues, 1938), but the basis of it consists of staining a section with red fuchsine, and counter-staining with aniline blue. The cortical cells in a normal specimen take the blue dye, but in virilism the cortical cells take the red fuchsine dye, and the cytoplasm assumes a vivid red colour.

Interpretation

The intensity and extent of the staining bear a definite relationship to the degree of virilism, but on the other hand a small gland with a vivid stain may produce the same signs as a larger gland with a less marked or patchy stain. It therefore appears to have a qualitative and quantitative value. These observations led to the supposition that the reaction was concerned with androgenic activity, and led to further biochemical investigations. When the gland has been removed it should be placed in formol-saline and not in formalin, as the latter destroys the fuchsine reaction.

Reaction in embryo

A wider application of the fuchsin stain in the sphere of embryology led to the observation that the response appears as a transitory phase in the foetus of both sexes. In the male it is more marked, lasting from the ninth to the seventeenth week; in the female it lasts between the eleventh and fourteenth week, and it then disappears. It would seem that the post-natal development of virilism is the reactivation of a physiological phase which occurs normally in the foetal adrenal.

Foetal virilism

The termination of this "male phase" in the female at the end of the fourteenth week does not always occur. In a few foetuses examined, it was present at birth, and then there were marked sex changes including an enlarged clitoris. The foetal adrenal is a comparatively large organ, and if it exerts a strong masculinizing effect on a female-determined foetus, at the time when the utero-vaginal canal is in the process of becoming differentiated (up to the sixteenth week) there is some reason to expect variations in the structure of the external genitalia. A brief reference to the possibility of this form of partial sex reversal taking place *in utero* is necessary, for without consideration of it the table of intersexuality given later becomes meaningless.

(2) Biochemical

The assumption that the fuchsine-stained material exercises a masculinizing effect has been correlated by stages with the following procedures, which may be regarded as tests for androgenic activity.

(a) Capon test

This biological test for androgenic substances is performed by measuring the comb growth produced by their injection into capons. The method was originally used by Patterson and Greenwood (1938) in our work, and the details have been published elsewhere. It gave the information that there was a comb growth-producing substance in the urinary extracts made from patients with virilism, which was less in amount after unilateral adrenalectomy. In this respect the test is satisfactory but is laborious, time consuming, and gives no clue to the nature of the active substance in the extracts. The problem was later solved by Marrian and Butler of Toronto, who isolated pregnane-triol, a compound specific to virilism, which was likewise reduced in amount by unilateral adrenalectomy. By breaking down pregnane-triol one of the first substances recovered was *iso*-androsterone.

Androgenic factor isolated

(b) Ketosteroid or colorimetric test

In 1938 Patterson adopted this test and from the surgeon's point of view it gives quicker results, which are nevertheless consistent with those of the capon test. It is a colour test, and the final reaction of the urinary extract is contrasted against a standard colour, but the colour fades and its interpretation is liable to individual variation. We have found several results from outside sources misleading and inaccurate, and the technique of the test requires standardizing and simplification. It is therefore necessary for the surgeon to become accustomed to one biochemical standard, which should conform to the clinical requirements for performing adrenalectomy. In suitable cases, the surgeon can expect an average of 50 per cent reduction in androgen metabolism from unilateral adrenalectomy.

Prognosis

4. THE ADRENO-GENITAL SYNDROME

The commonest manifestation of the adreno-genital syndrome is the clinical condition of virilism. Virilism may be defined as the appearance of male secondary sex characteristics in the female. The earlier the signs appear the more marked they are. When they appear later, they may be complicated by secondary symptoms due to polyglandular disturbances. Virilism may be classified into four main groups:

Virilism defined and classified

Group I. Pre-puberal virilism.
Group II. Post-puberal virilism.
Group III. The Cushing or fat type.
Group IV. Post-menopausal virilism.

(1) Group I. Pre-puberal virilism

Age incidence

Pre-puberal virilism becomes manifest at puberty when the secondary female sex characteristics and the sex function fail to appear in girls. Occasionally it may be established at birth, when a large clitoris is present, and later is followed by the precocious development of pubic and axillary hair at the age of from five to ten years. These children are of the tomboy type; they have short limbs with a muscular torso, and show a preference for active games; the voice may be rough and deep. If they reach puberty without these signs, then obvious changes occur in two directions, the failure of feminine development and the appearance of secondary male sex characteristics (Fig. 38).

Course



FIG. 38.—Pre-puberal virilism, illustrating the typical appearance of the figure and distribution of hair.

Clinical picture

The figures of these girls are boyish, the shoulders are broad and the pelvis

narrow, the lower jaw and supra-orbital ridges are accentuated and the general muscular development stands out in contrast to the normal soft rounded contour of the female. On the female side the menses do not start, the breasts fail to grow, the external genitalia remain puelline, the uterus and cervix are infantile and the ovarian follicles do not ripen. Hair of the curly crisp type (Fig. 39 (*a*) and (*b*)) begins to grow on the face, limbs and trunk, and shaving becomes necessary. The voice cracks and becomes deep and rough. The clitoris is enlarged and the labia and vaginal orifice are small and narrow. It is not surprising that such gross changes should have a marked effect upon the personality of the patients. They tend to withdraw snail-like within themselves and shun society. At this early age it is not easy to assess their sexuality, and in spite of their female conditioning, it may be neuter, indifferent, or homosexual; indeed one patient, after behaving as a male, was subsequently married twice as a female. The condition progresses, and these patients look much older than their age, and may start to become bald at their twentieth year.

Psychological effects

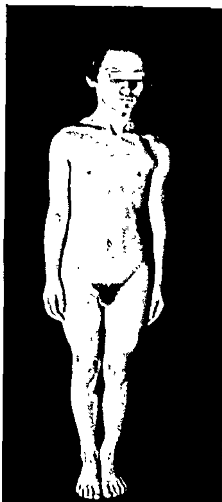


FIG. 39 (*a*).—Pre-puberal virilism in a patient aged 8 years.



FIG. 39 (*b*).—Pre-puberal virilism; same patient as in Fig. 39 (*a*) at 14 years of age.

(*a*) *Pathology*

There is bilateral hyperplasia of both adrenal glands. They may reach the size of a normal spleen. The larger they are, the more they are pigmented. The ponceau-fuchsine reaction is strongly positive. The uterus, cervix uteri and uterine tubes are infantile; the ovaries are solid and smooth, and may contain some small cysts, but they do not ripen and no corpus luteum is present.

(*b*) *Biochemistry*

The excretion of androgens in these cases is high, and ranges from three to

five times above normal. After unilateral adrenalectomy the average reduction is 50 per cent, but varies in different subjects. As the remaining adrenal is still several times larger than normal, the androgen excretion rises as the patients grow older.

Post-operative result

(*c*) *Pre-operative considerations*

The condition is progressive and unilateral adrenalectomy is prophylactic. In spite of their sturdy appearance these patients are bad operative risks. In our series they represent 10 per cent of the number of cases operated upon for secondary virilism. After unilateral adrenalectomy including the preliminary laparotomy, there has been one death due to an enlarged thymus and collapse of both lungs. There is marked post-operative shock, and the patient goes into a condition resembling acute hyperthyroidism, with a mounting pulse rate and falling blood-pressure. Aqueous solution of iodine (Lugol's solution) has a beneficial effect.

Operative risk

Shock

(*d*) *Prognosis*

In order to get the maximal effect, the earlier unilateral adrenalectomy is performed the better, and the prognosis is better where hyperplasia is not too marked. Several of our patients have become useful citizens; they are able to pluck their facial hair out easily, and in some the menstrual flow has been induced by organotherapy.

(*e*) *An extreme case*

At the age of eight, the left and larger adrenal was removed with the following biochemical results:

Biochemical results

pre-operative	
ketosteroid test	37 milligrams per diem
capon test	68 units
post-operative	
ketosteroid test	22 milligrams per diem
capon test	5 units

This patient was closely observed; no secondary female sex characteristics developed during puberty, there was a beard, a deep voice, and the bodily contour was coarse, stunted and thick-set. The condition was obviously progressing, and the home and social atmosphere was becoming impossible for the child. At the age of 14 it was decided to try a subtotal resection of the remaining gland, and eighteen twenty-fifths (by weight) was removed. The patient died within a few days, repeating our previous experience of a pulse rate rising to 150 per minute, with a corresponding fall of blood-pressure. The pre-operative androgen excretion was 70 milligrams per diem.

Clinical picture

Course

Treatment

Results

(*f*) *Differential diagnosis*

There are three other types which are clinically indistinguishable from Group I virilism. They are the true hermaphrodite, the intersex, and the cryptorchid. It is only by laparotomy and biopsy of the sex gland that a definite diagnosis can be made. The androgen output may be raised in these cases, but not nearly so high as in Group I virilism. These conditions are referred to in the table of intersexuality.

(2) Group II. Post-puberal virilism

It is to this group that the majority of our patients belong. It is about ten times commoner than Group I virilism. Many of these patients are instances

Numerical incidence

narrow, the lower jaw and supra-orbital ridges are accentuated and the general muscular development stands out in contrast to the normal soft rounded contour of the female. On the female side the menses do not start, the breasts fail to grow, the external genitalia remain puelline, the uterus and cervix are infantile and the ovarian follicles do not ripen. Hair of the curly crisp type (Fig. 39 (*a*) and (*b*)) begins to grow on the face, limbs and trunk, and shaving becomes necessary. The voice cracks and becomes deep and rough. The clitoris is enlarged and the labia and vaginal orifice are small and narrow. It is not surprising that such gross changes should have a marked effect upon the personality of the

Psychological effects

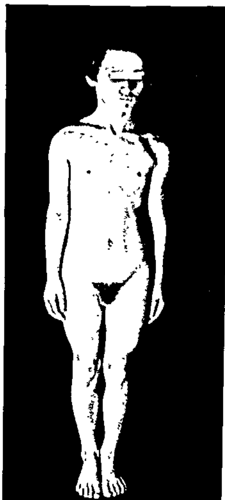


Fig. 39 (*a*).—Pre-puberal virilism in a patient aged 8 years.



Fig. 39 (*b*).—Pre-puberal virilism; same patient as in Fig. 39 (*a*) at 14 years of age.

patients. They tend to withdraw snail-like within themselves and shun society. At this early age it is not easy to assess their sexuality, and in spite of their female conditioning, it may be neuter, indifferent, or homosexual; indeed one patient, after behaving as a male, was subsequently married twice as a female. The condition progresses, and these patients look much older than their age, and may start to become bald at their twentieth year.

(*a*) *Pathology*

There is bilateral hyperplasia of both adrenal glands. They may reach the size of a normal spleen. The larger they are, the more they are pigmented. The ponceau-fuchsine reaction is strongly positive. The uterus, cervix uteri and uterine tubes are infantile; the ovaries are solid and smooth, and may contain some small cysts, but they do not ripen and no corpus luteum is present.

(*b*) *Biochemistry*

The excretion of androgens in these cases is high, and ranges from three to

follow-up of these cases has been impossible during the war. Medical treatment is limited in scope, and until some anti-androgenic factor is discovered, operation is the treatment of choice.

(3) Group III. The Cushing or fat type

Clinical picture

This group is common, being composed of hefty, hairy women, the onset of whose symptoms is similar to that in Group II, with the difference that they run to fat. They comprise varying grades between the extremes of Group II and Cushing's syndrome, with or without one or more of the secondary symptoms of the latter. Usually menstrual disorders are more marked than hirsuties. In those patients who have a high output of androgens, adrenalectomy should be carried out, and generally the fuchsine reaction is positive in the gland.

Treatment

Treatment is primarily medical: a low-calorie diet with fixed fluid intake, iodides and oestrogens.

(4) Group IV. Post-menopausal virilism

Group IV comprises those bearded women after the menopause, so often seen in mental wards. Adrenalectomy is contra-indicated.

5. CUSHING'S DISEASE

(1) Definition

Cushing's syndrome may be defined as secondary virilism, to which a pathological obesity and other secondary metabolic symptoms are superadded.

(2) Clinical picture

The onset of hirsuties and menstrual irregularities is the same, and in the same age group, as in Group II. At this time the patient begins to develop a gross adiposity, accompanied by a ruddy complexion. This red colour is also distributed over the breasts and extremities, and in the form of livid red striae distensiae radiating round the pubes, on the abdomen, flanks and groins. Hair is not so marked and is more of the downy type. Amenorrhoea is common (Figs. 40, 41, 42).



FIG. 40—Cushing's disease, showing the obesity and skin shine characteristic of the pituitary syndrome.

Patients of this type have a low basal metabolic rate as in myxoedema, but after surgical intervention they become anxi[illegible]
rate resembling hyperthyroidism

of familial hirsuties, and their symptoms are mild and do not require operation. It is commonest among Jews, and in the offspring of parents of mixed nationalities. In some the condition seems to arise from endocrine imbalance during pregnancy, especially in twin pregnancies. Other endocrine lesions are fairly often traced in the family histories.

Race incidence

(*a*) *Clinical picture*

In this group, the patient having passed normally through puberty, usually between the ages of fifteen and twenty-five, begins to grow hair of the male type and to experience irregularity or cessation of the menstrual function. In some there is a temporary increase in weight, and severe headaches of the migrainous type may occur. Exactly the same symptoms, with regard to the retardation of the feminine characters and functions, and the accentuation of male characters, occur as in Group I, but to a lesser degree. The severity of one or other of the more undesirable symptoms, or their combination, must be the clinical guide with regard to the performance of unilateral adrenalectomy.

Amenorrhoea

Migraine

(*b*) *Psychological*

Although the majority of these women are normally heterosexual, it is in this group that the most marked psychological changes have been observed. They occur in varying degree. Changes in sexuality range from autosexuality (narcissism) to frigidity, and to overt or frank homosexuality. In a few there has been paranoid psychosis, in which anorexia of the nervosa type, delusions and persecution complex play a part, leading to suicidal tendencies. The details of these conditions are a specialized study and have been published elsewhere by Clifford Allen (1938). Psychological reaction may be temporarily aggravated by unilateral adrenalectomy, but on the whole these unpleasant symptoms have been improved by operation, and in this respect the psyche and soma have run on parallel lines.

Sexual perversions

Paranoia

(*c*) *Pathology*

There is a bilateral hyperplasia of the adrenal glands, which vary from two to three times their normal size. The ponceau-fuchsine reaction is invariably present in the cortical cells, and its intensity bears a direct relation to the degree of virilism present. The results are better in those patients from whom the larger gland is removed.

(*d*) *Biochemistry*

The excretion of androgens is raised, and the output forms an extremely helpful guide, when taken in conjunction with the clinical picture, in deciding the question of performing unilateral adrenalectomy. The average decrease in output after operation is 50 per cent and the larger the decrease the better the result.

(*e*) *Prognosis*

The prognosis in these cases is good. In one hundred unilateral adrenalectomies including laparotomy, in this group, there has been no mortality. The facial hair can be plucked out fairly easily and without much pain within 48 hours of the operation. The complexion and any acne of the skin are improved, menstruation is less irregular, and fertility and sexuality are increased. The degree of improvement varies and can be subsequently helped by hormonal therapy if necessary. The majority of these young women are satisfied that something, at least, has been done for an unpleasant and embarrassing condition, which gives a guarantee against its further progress. Systematic

(4) Treatment

(*a*) *Adrenal syndrome* *

When the ketosteroid test reveals a high output, laparotomy followed by removal of the larger adrenal should be performed

(*b*) *Pituitary syndrome* *

In our experience x-ray treatment to the pituitary fossa has not been helpful. We have recently adopted a form of treatment which has proved successful. It is purely empirical and theoretically aims at influencing the pituitary effects via the thyroid gland and ovary.

Case history

A girl twin of sixteen years was suffering from Cushing's syndrome. She was short, florid and fat. The ketosteroid test done elsewhere was 22 milligrams per diem, but our result was 14 milligrams per diem. She had primary amenorrhoea, her bones were rarefied with some collapse of two lumbar vertebrae, and she was nursed in a spinal jacket. She developed bronchitis, oedema, and a rapid pulse and appeared moribund. She was given Embleton's diet, with a 50-ounce fluid intake, aqueous solution of iodine (Lugol's solution) 10 minims thrice daily and an oestradiol implant into the groin. She slowly improved, started to menstruate, and some months later had lost most of her weight and could walk eight miles a day.

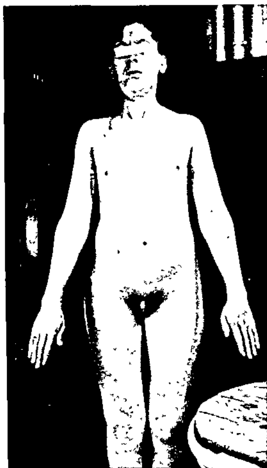


FIG. 43.—To show the physical characters of feminism.

Treatment with a testosterone implant was tried in a similar case of a soldier. He did not respond to the same extent as in the previous case, and as his ketosteroid output remained in the region of 30 to 50 milligrams daily, unilateral adrenalectomy was performed. On discharge from hospital he had lost two and a half stones in weight.

6. FEMINISM

(1) Definition

Feminism of the male is the counterpart of virilism in the female, and may

* The term "basophilism" is sometimes employed. Crooke's hyaline cells are nearly always present in the pituitary with the adrenal syndrome.

Biochemical investigations

The secondary symptoms are revealed by special investigations. There is erythrocythaemia with a raised colour index; there is excess of cholesterol in the blood and a low sugar tolerance, verging on glycosuria.

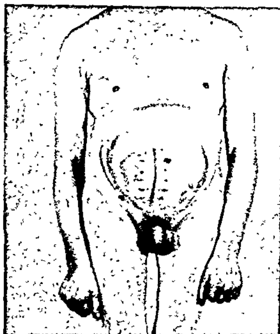


FIG. 41.—Cushing's disease, to show adiposity of the trunk with little or no change in the limbs.

A skiagram of the pituitary fossa generally shows a small sella. The blood pressure is raised.

(3) Differential diagnosis

Ketosteroid test

It is impossible to determine on clinical grounds whether the condition is due to basophil adenoma of the pituitary, or to hyperplasia or neoplasm of the adrenal cortex. If the ketosteroid test is within normal limits, a diagnosis of pituitary basophilism can be made. If it is moderately raised adrenal hyperplasia is present, and if excessive adreno-cortical carcinoma may be diagnosed. On our standard, the normal limits range from 7 to 14 milligrams per diem. An excretion of 30 milligrams or more would indicate adrenal hyperplasia. One case of adrenal carcinoma excreted 270 milligrams per diem. Judged from a limited experience, osteoporosis would favour a diagnosis of pituitary adenoma, whereas normal or sclerosed bones would suggest an adrenal origin.

Criteria



FIG. 42.—Cushing's disease: extreme degree of adiposity of the trunk, and excess of facial hair.

Clinical picture

dusky complexioned, lethargic and pot-bellied, the infant Hercules type. The external genitalia are adult in proportion, with erections; facial, pubic and axillary hair appears prematurely. Girls have the same bronzed colour, the body is stout in contrast to the short thin limbs, the breasts enlarge, pubic and axillary hair sprouts, and menstruation commences.

Pathology

An adenocarcinoma is invariably present and it is most important to realize that this neoplasm may be present in a solitary adrenal gland. The

Biochemistry

ponceau-fuchsine reaction is found positive in the carcinoma cells, and in the secondary deposits, and the androgen output is increased. According to our standard, the normal output is about 2 to 3 milligrams per diem for a child. Crooke's hyaline cells are present in the pituitary gland.

Differential diagnosis

Differential diagnosis must be made from heterosexual precocity in girls (pre-puberal Group I virilism) where there is an enlarged clitoris, pubic and axillary hair. Isosexual precocity may occur with tumours in the region of the hypothalamus, which are notoriously difficult to diagnose. A normal or low androgen output would suggest this origin. If adrenal tumour is suspected, laparotomy is indicated.



Fig. 44.—Sexual precocity in a child with a solitary adrenal tumour.

Prognosis and course

The prognosis is bad and these children die young. They are prematurely aged, and each year of their life corresponds to a decade of the normal. Their manners are precocious and their early sexuality may become a nuisance. Their baby ways contrast strangely with their adolescent minds, and some of them are unusually clever in special directions.

The adrenal carcinoma cases soon die from secondary spread.

Those with hypothalamic tumours usually die from some intercurrent malady.

Of three girls of this type, adrenalectomy in one produced no result; encephalograms in another indicated no diagnosis; the third was left alone.

(2) Tumours of the adrenal medulla

The cells of the adrenal medulla consist originally of primitive neuroblasts, and give rise to tumours either of the sympathetic neurones or the chromaffin

be defined as a retrogression in the primary and secondary male sex characteristics after puberty (Fig. 43).

(2) Clinical picture

This condition is uncommon, and there is some justification for including it under the adreno-genital syndrome.

After puberty the penis and testes remain small, the voice does not crack, and the beard does not grow. The body is long, the limbs are long and spindly, the fingers taper, and the pelvis is relatively wider than the chest. There is not the blubbery fat of the eunuch, although it is increased over the breasts and hips. The appearance is juvenile, the epiphyses unite late, and the sexuality tends to be neuter.

(3) Prognosis

Illustrative case

In one case, unilateral adrenalectomy was performed. The ponceau-fuchsine reaction showed good staining. The patient received some benefit. His penis and testes increased in size, his voice dropped somewhat, he shaved occasionally, his height increased one inch at the age of thirty-two, he put on weight, became more self-confident and aggressive, and his sexuality appeared definite. The pre-operative ketosteroids were low for a male, and were further reduced by adrenalectomy. The output of oestrogens was unaffected.

(4) Differential diagnosis

Feminism of the male must be distinguished from the congenital malformations associated with retarded male development, which occur in cases of undescended testes and cryptorchidism, with or without cleft scrotum. These types are discussed in the table of intersexuality.

7. TUMOURS

Tumours of the adrenal cortex and medulla may be simple or malignant, physiologically active or inert.

(1) Tumours of the cortex

(*a*) *Simple*

Adenomas of the adrenal cortex are rare. They produce sex changes with extreme rapidity; return to normal after removal of the tumour is equally dramatic.

Two successful cases have been reported and in one of these photographs taken before and after operation show the extraordinary change in demeanour, so expressive of personality, from the confident male to the shy and demure female.

(*b*) *Malignant*

Types

There are two types of malignant tumour: those which produce sex changes, and those which do not.

The physiologically active neoplasms produce different clinical pictures according to their time of onset. Those developing before puberty produce isosexual precocity in both sexes (Fig. 44); in the adult, Cushing's syndrome in the female and feminization of the male have been encountered.

Isosexual precocity

Isosexual precocity may be defined as the premature appearance in the child of the corresponding sex characters and functions of the adult. Boys become

Description of attack

exert a powerful physiological effect and produce hypertension. This may be constant or paroxysmal. Patients during a paroxysm feel faint, anxious and apprehensive, and may collapse. The face may be pale and moist and the extremities cold and blue. These vasoconstrictive attacks vary in severity, and may be associated with nausea, giddiness, headache, palpitations and weakness in the legs. During the attack, the blood-pressure is raised. These vague symptoms are apt to be ascribed to a neurosis, and unless the condition is kept in mind, it is easily overlooked.

Case history

The condition is rare. One case has been reported with complete transposition of viscera and mild signs of feminism. The tumour, a phaeochromoblastoma of 63·5 grammes, was removed, and contained an excess of adrenaline. During the operation, the blood-pressure rose to 225/145, and within ten minutes of removing the tumour it fell to 90/70, and had to be restored by an intravenous injection of adrenaline. A retrograde pyelogram revealed a deformed upper calyx of a depressed left kidney, which was confirmed by laparotomy. Peri-renal insufflation did not outline the shape of the tumour, but this was probably obscured by the shadow of the transposed liver. The patient has remained completely free from his previous symptoms.

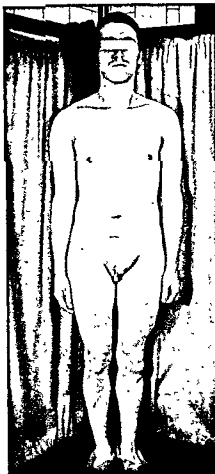


Fig. 47.—Cryptorchid with retained abdominal testes; the patient was brought up as a girl. Note the cleft scrotum.

Another patient suffering from similar symptoms died during a paroxysm while being investigated. Here, an intravenous pyelogram revealed a depressed upper calyx of the right kidney, and necropsy confirmed this as the site of the tumour.

Age incidence
Prognosis

These tumours are generally benign and tend to occur after the age of forty. If diagnosed before the vascular system has been too strained, the prognosis is excellent.

8. INTERSEXUALITY

Diagnostic importance

It is necessary to draw attention to the problem of intersexuality, not only to stress its importance in differential diagnosis, but also to show what part the adrenal glands play in its production.

Sex reversion

Complete sex reversion is a biological phenomenon, which normally occurs in the adult stage of certain lower animals, such as birds and fishes. In man, the process is only partial. There is some reason to believe that during the

cells. They are the precursors of three types of tumour, two of which are physiologically inactive, and one strongly active.

(*a*) *Inactive*

Ganglioneuroma

Ganglioneuromas are rare, generally benign, they may occur in children or adults, and have a tendency to become multiple.

Neuroblastoma

Neuroblastomas occur in children. They are highly malignant. Their cells tend to be arranged in rosettes. They are characterized by extensive meta-



FIG. 45.—Hermaphroditism in a patient who was shown to have bilateral ovotestes.



FIG. 46.—The clinical picture of intersexuality.

stases, which show a definite distribution according to the gland involved. On the right side (Pepper's syndrome) metastases occur in the liver, and may reach enormous dimensions, and on the left side (Hutchison's syndrome) the secondary deposits are mostly confined to the bones, and there is usually proptosis and ecchymosis of the left eye.

Pepper's syndrome

Hutchison's syndrome

Medullary tumours

Medullary tumours may produce a weak fuchsinophil reaction in the cortical cells. Clinical observation may disclose mild sex changes which may prove helpful in arriving at what is a difficult diagnosis.

(*b*) *Active*

Vasopressor effect

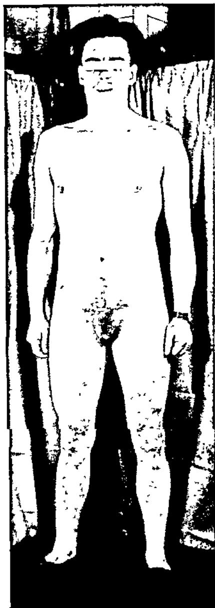
Paragangliomas, tumours of the chromaffin cells or adrenaline tumours,

compilation of the pathology of this table of intersexuality. From the time that testicular tissue appears and increases in amount, so the adrenal glands return to their normal proportions, and androgen output decreases, but the masculinizing effect continues and is complete with full development and descent of the testes.

Social problem

These subjects of arrested sex development, whose final form is determined only after puberty, constitute a difficult social problem. The majority are erroneously brought up as girls. Where the sexuality is predominantly male, plastic surgery can do much to help them. When it is female, amputation of the clitoris and undeveloped testes should be performed. Before puberty it is difficult to determine sexuality and more difficult still to forecast its future nature.

Surgical treatment



9. PRE-OPERATIVE INVESTIGATION

Ketosteroid test

The ketosteroid test gives the best indication of the degree of adreno-cortical activity.

Blood investigation

In Cushing's syndrome, the blood-pressure, blood-count, blood-sugar and blood-cholesterol should be determined.

(1) For hyperplasia

Laparotomy

Laparotomy is a safe and useful guide for determining which adrenal to remove. A paramedian incision long enough to admit the hand is made to the right of the umbilicus. The pelvic organs are palpated to detect any abnormality, and to exclude arrhenoblastoma of the ovary or aberrant adrenals. Each adrenal is then palpated to see which is the larger. In the majority of cases, this can be done satisfactorily. The adrenal is generally larger on the same side as the more degenerate ovary. Laparotomy is a safe procedure and seems preferable to the simultaneous exposure and removal of a portion of each adrenal gland. Adrenalectomy can be performed a fortnight later.

Adrenalectomy

(2) For tumour

An intravenous and if necessary a retrograde pyelogram should be performed. Distortion of the upper calyx

course of higher evolution this baneful legacy has been relegated to foetal life. As we have to judge final results, the gonads and external genitalia, the late clinical manifestations would seem to be determined during those early weeks of foetal life, when, as we have already seen, the opening and closing of the utero-vaginal canal corresponds in time with the integration of the foetal endocrine system. Indeed, in the course of studying our clinical material, there are six clearly defined groups, which represent different stages of this incomplete or arrested sex development, and by correlating their pathology it has been possible to draw up the following table of intersexuality.

Clinical groups

	OVARY	UTERUS	VAGINA	CLITORIS	TESTES	ADRENAL
Female						
Secondary virilism	Cystic	Small	Small	Slightly enlarged	None	Large
Primary virilism	Functionless	Smaller	Smaller	Enlarged	None	Very large
Hermaphrodite	Ovotestes	Tiny	Smaller	Larger	Ovotestes	Large
Intersex	None	Tiny	Smaller	Larger	Embryonic abdominal	Large
Cryptorchid	None	None	Cleft scrotum	Penile	Retained abdominal	Normal
Undescent	None	None	None	Penis	Various stages of undescent	Normal
Male						

Discussion of table

Patients described in this table have fallen naturally into each group. It is seen that the appearance of male characteristics starting in secondary virilism become more marked and intensified in primary virilism. Pathologically there is an increased hypertrophy of the adrenal glands, and a higher output of androgens. Here the adrenal glands play the part of accessory male organs at the expense of ovarian function. At the same time there occurs a corresponding diminution in the development of female sex characteristics and their function.

In the hermaphrodite stage, the fusion of the two sexes is complete. There may be bilateral ovotestes and a primitive ovary on one side and a primitive testis on the other (Fig. 45).

The following or intersex group presents the anomaly of an undeveloped uterus in the presence of immature testes placed in the position of the ovaries (Fig. 46).

The cryptorchid with retained abdominal testes and a penile cleft scrotum is only a stage further advanced (Figs. 47 and 48). Indeed secondary virilism, hermaphroditism, the intersex and cryptorchid are clinically indistinguishable except for the preponderance of androgens in primary virilism. We have had to resort to laparotomy and histological examination of the gonads for the

(2) The high kidney incision

Technique

An incision six to eight inches long is made parallel to the last rib and the muscles divided. If the last rib is small it is resected subperiostally and entrance gained into the perinephric fat by incision through its bed. If it is a large rib, two holes are made an inch apart at the neck, and the rib divided between them. A strong ligature is threaded through the holes and left *in situ* to be tied when closing the wound. The perinephric fat is opened, the kidney held down with a special retractor, and a deep retractor pulls up the ribs. The adrenal gland is defined and caught in special forceps. Positive pressure is now applied by the anaesthetist and the gland dissected from its bed. The main vein seen on its upper surface is then tied and the gland freed and removed (Fig. 49). The vein is friable and if torn off may give rise to alarming haemorrhage. This is more likely to happen if the diaphragm or vena cava is allowed to flap. The rib is then tied and the muscle layers are sewn up with interrupted catgut. No drain is necessary and the skin is closed. Dependent upon the width of the subcostal angle, the pleural or peritoneal cavity or both may be accidentally opened.

This operation requires rather a shorter convalescence than the thoracic one, after which the lung may take some time to expand.

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[References to other titles are given under Adrenal Glands in the Index Volume. The subject of Adrenal Gland Diseases is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 232.]

and depression of the kidney gives the earliest hint of the presence of a tumour.

X-ray examination unsatisfactory

X-ray examination after peri-renal insufflation with air or oxygen by means of a needle attached to a manometer has not proved of great value. Laparotomy is safe and gives more precise and general information.



FIG. 49.—View of right adrenal gland showing main vein going into inferior vena cava.

10. OPERATIVE TECHNIQUE

Unilateral adrenalectomy may be performed through the chest or a high kidney incision. Special instruments and retractors are necessary.

(1) Thoracic approach

Technique

An incision is made along the intercostal space between the tenth and eleventh ribs. The thoracic cavity is opened, the ribs are retracted, and the diaphragm incised. The adrenal is held in special forceps and dissected from its bed, and the wound closed.

principles to less severe cases leads to shortened convalescence and improved end results.

Immobilization and local atrophy

Severe injuries and extensive operations require longer immobilization for healing, with consequent increase in the risk of stiffness and muscle atrophy in the immobilized parts. The risk is increased by multiple wounds and the complete immobilization facilitated by modern plaster-of-Paris technique. This can be offset by the earlier resumption of activity which may be allowed if the tissues are adequately supported.

Deterioration of general physique

Impairment or loss of function in the disabled parts is to be expected; but less well recognized is the deterioration of the general physical and mental functions consequent upon illness and hospitalization. The extent of this general atrophy is dependent upon the severity and duration of illness. It is greatly increased by toxaemia and manifest by loss of weight, tone and power in muscles and diminution of the capacity for sustained mental effort.

Recovery of function in relation to occupation

Before recovery from illness or injury is complete patients must have regained the degree of physical and mental endurance required to perform a full day's work without undue fatigue or deterioration of skill towards the end of the day. The requirements of each individual are dependent upon the nature of his work. For example, the dock labourer needs great physical endurance; the clerk capacity for sustained mental effort; the mechanic manual dexterity combined with accuracy in the interpretation of working drawings.

From this it follows that measures to assist recovery must be related to the functional needs of individual patients as well as to surgical correction or alleviation of the pathological process involved.

(2) Economic and social

Social factors influencing convalescence

The incentive to recover and the restoration of self-confidence are impaired by long and debilitating illness, knowledge or fear of permanent disability, loss of employment consequent upon illness and uncertainty about the availability of work when recovery is complete. Given time and normal incentive most patients regain the physical and mental capacity for their work unaided, but often the process is protracted with economic hardship to the individual and to the State. A proportion of patients, more especially those engaged in arduous occupations and those with neurotic tendencies, fail to regain the ability to work even though they may have recovered from the surgical lesion.

Chronic disability

These patients drift into chronic invalidism and unemployment or, at best, into casual unskilled labour. In the past many skilled workers have been permanently lost to industry in this way.

The natural restoration of capacity for full work is achieved when the individual is able to resume his work by easy stages. This was facilitated by the shortage of labour in war-time, but in peace and especially during periods of industrial depression, industry provides few opportunities for restricted hours or modified work. Moreover, in the past, national health insurance, workmen's compensation and disability pensions have tended to discourage the resumption of any work until the individual is convinced that he is fit for full work and unlikely to break down again.

Undue delay in return to work

Consequently, patients have hesitated to discard disability allowances, however inadequate, and have delayed return to work until long after they are fit to do so.

AFTER-CARE—INTRODUCTION

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1. HISTORY

13.] In the past, surgical responsibility tended to end with the discharge of patients from hospital and scant attention was paid to the effect of surgical illness on the ability of patients to return to their normal mode of life. Commencing with the pioneer work of the late Sir Robert Jones during and immediately after World War I, and accelerated by the clinical, economic and social problems arising during both World Wars and the intervening industrial depression, systematic after-care or surgical rehabilitation has developed into a subject of major importance.

2. EVOLUTION OF SYSTEMATIC AFTER-CARE

(1) Clinical

Greater incidence and severity of injury

The extension of mechanization to so many forms of human activity has increased the number of injuries in industry, on the roads and by weapons of war. At the same time the greater weight and speed of machinery, transport and missiles have increased the damage inflicted on the tissues. Concurrently with the increase of severe injuries improvements in surgical technique, blood transfusion and anaesthesia have improved the chances of survival and thus added to the number of patients with severe permanent disability. Furthermore, progress in surgery has made possible more extensive operations in all branches of the subject so that many patients are recovering from more severe lesions than in the past. As a result of the experience gained in the treatment of severe disability it is now recognized that application of similar

Increase in permanent disability

any, of earning capacity; claims are dealt with by Industrial Pensions Officers and disputes are subject to appeal to Tribunals.

(c) *The National Health Service Act* 1946

Provisions in this Act include "treatment during convalescence and medical rehabilitation" in the summary of the proposed new service, thus continuing the provisions for rehabilitation established by the Emergency Hospital Service of the Ministry of Health.

4. RESPONSIBILITY OF THE SURGEON

Disability in relation to occupation

In the past, surgery has been directed to the correction or alleviation of morbid processes and the restoration of anatomical function after injury, without sufficient regard to the fact that the same lesion and surgical repair may prove little handicap to one patient, but will prevent another from returning to his usual occupation. For example, ankylosis of the radio-ulnar joints midway between pronation and supination is the most useful position for the majority; but the shorthand typist is most likely to regain her ability for full work if the limb is fixed in pronation. Again, a successful operation is of limited service to the patient if he fails to regain the ability to work or breaks down again due to returning to unsuitable employment. This may happen if a patient with a healed peptic ulcer returns to work involving irregular mealtimes or a miner returns to the pit before he has regained full mobility and muscle strength after a fractured spine. Furthermore, recovery after successful surgical treatment may be marred by inadequate convalescent treatment to restore function and by vocational training which is unsuited to the mental and physical capacity of the individual.

Therefore, the surgeon must modify the early surgical management in the light of the ultimate functional activities of the individual and ensure that the convalescent treatment and vocational resettlement are best suited to each case. Much of the detail of remedial treatment, vocational training and resettlement in industry is remote from everyday surgical practice, and may be entrusted to specialists in the various subjects. But successful after-care depends upon continuity of supervision throughout by the surgeon who undertakes the primary treatment.

Continuity of after-care

5. RESTORATION OF FUNCTION

(1) Physiotherapy

The essential features of the early stages of surgical rehabilitation are: massage; electrical stimulation of muscles; radiant heat or diathermy to relieve pain and assist the absorption of inflammatory transudates; elimination of effect of gravity by support in water or slings to assist the exercise of very weak muscles; prevention of stiffness and muscle atrophy in immobilized structures.

It is important to ensure that these agents are used with sufficient intensity, duration and frequency to be effective and that they are discontinued when the patient has improved sufficiently to complete the restoration of function by active remedial exercises and purposeful occupation.

The solution of the problem is found in co-operation between the medical and social services to provide continuous and systematic measures from the onset of sickness or injury until the patient is restored to his former mode of life and work or, in the case of the permanently disabled, trained and settled in work best suited to his residual mental and physical capacity.

3. ORGANIZATION

(1) Ministry of Health—surgical

The following are among the services provided:

(i) Integration of early surgical management with the ultimate function of the patient.

(ii) Therapeutic measures to prevent undue physical and mental deterioration consequent upon illness and hospitalization and designed to accelerate the restoration of maximal function in the disabled parts and the body as a whole.

(iii) Social welfare by qualified almoners to apply statutory and other services to relieve want and anxiety during hospitalization, and to provide continuity between the hospitals and the later stages of convalescence and industrial resettlement.

(2) Ministry of Labour—industrial

The following are among the services provided:

(i) Pre-vocational hardening centres for those who have lost confidence and the ability to work after long or severe illness.

(ii) Vocational training centres for the permanently disabled.

(iii) Social welfare by specially trained officers of the Ministry of Labour (Disablement Resettlement Officers) to provide continuity with the hospitals, admission to training centres and resettlement in industry.

(3) Statutory provisions

(a) The Disabled Persons (Employment) Act 1944

The provisions of this Act cover all persons other than children and inmates of mental hospitals "whose disability is likely to last more than six months and are substantially handicapped in obtaining and holding work suited to their age and qualifications". The Act is operated by the Ministry of Labour and provides for a register of disabled persons, pre-vocational hardening centres, vocational training centres, Disablement Resettlement Officers based on local Employment Exchanges, local Advisory Committees and Medical Panels to determine eligibility for registration, subsistence allowances during hardening and vocational training and compulsion on employers with twenty or more employees to give priority to a quota of disabled persons for work which is within their capacity.

Priority for the disabled

(b) The National Insurance (Industrial Injuries) Act 1945

This Act covers "all persons employed in insurable employment" against injuries arising in the course of their employment. Provision is made for contributions to the National Insurance Funds by employers and employees; claims are made against the Fund and not against individual employers; subsistence allowances are payable during treatment; pensions for permanent disability are based on physical or mental defect and are not related to loss, if

Industrial injuries

Disability pensions

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(2) Group exercises and games

Need for sustained exercise

Patients cannot recover the physical endurance necessary for arduous work by a short period of individual remedial exercises in the physiotherapy department. In the past, failure to restore adequate muscle power by sustained exercise has been a major factor in the prolongation of convalescence and breakdown after attempting to resume work. The modern practice of grouping patients with similar disabilities permits adequate periods of remedial exercise with economy of staff. Patients are stimulated by working together, and the monotony of purely remedial gymnastics can be avoided by the use of games selected to provide the particular muscle work required.

(3) Occupational therapy

This combines physical and mental exercise for the purpose of creative work. Two distinct forms of occupational therapy may be recognized.

Hospital curative workshop

First, in hospital practice a variety of handicrafts not necessarily related to the normal occupation of the patients are used by the occupational therapists to encourage the movement and muscle work required, whilst interest in the work distracts the attention from the disability. Occupational therapy encourages restoration of movement and muscle power within the functional range, whilst remedial exercises are more effective to restore anatomical range and maximal power.

Industrial curative workshop

Secondly, in industrial practice and the pre-vocational hardening centres, occupational therapy is in the form of the normal occupation of the patient, modified according to the degree of disability, and provides for the resumption of full work by easy stages or work suited to the residual capacity of the permanently disabled.

6. REMEDIAL TREATMENT

In certain circumstances surgical rehabilitation commences with treatment before operation, such as teaching quadriceps contractions before removal of the semilunar cartilage of the knee or diaphragmatic breathing before upper abdominal operations. In general, however, treatment to prevent undue deterioration and to promote the restoration of function should be instituted as soon as the patient is capable of response. In the early stages short periods of activity must be interspersed with long rest intervals, but, as the patient improves, the duration of activity should be increased and variety introduced by a balanced programme of physiotherapy, remedial exercises, games and occupational therapy. The aim should be to spur the patient on to greater effort by constantly increasing the demands made upon him. To this end the details of treatment should be reviewed at least once a week.

Progression of treatment

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[References to other titles are given under After-care in the Index Volume.]

AFTER-CARE–FOLLOW-UP

By SIR JAMES WALTON, K.C.V.O., M.S., F.R.C.S., Hon. F.A.C.S.
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End-results not recorded

14.] Even as recently as the early years of this century it was evident that surgeons had very little knowledge of the end-results of their treatment. So optimistic is human nature that unknown results are always believed to be satisfactory, and unless constant observation and analysis is kept of these late results there is very grave danger that the surgeon will persist with the methods he has learnt in early life, will make no progress and will soon become out of date.

A few surgeons early attempted to become acquainted with the end-results of their treatment by advising their patients to attend for later observation or even by writing to them after long intervals. It was found, however, that with such a method a very high proportion of the cases were lost. If thirty or forty of the patients were untraced they were either looked upon as cured or eliminated from the final computation, and the statistics, upon which so much stress was often laid, were thus entirely fallacious.

Special department

It became manifest to me after World War I that to appraise the value of my own surgical efforts a special follow-up department was essential. Not only could end-results thereby be ascertained, but after-treatment could be controlled and regulated. The modern appreciation of the importance of rehabilitation makes such a department all the more necessary. The department was opened in 1919 and continued uninterruptedly until 1939, so that its value has been demonstrated by twenty years' experience.

Analysis, revision and filing

Even with such a department, constant personal analysis and revision of figures is essential if the greatest benefit is to be obtained. Therefore the complete case histories, notes of operation, ancillary investigations and follow-up notes must be easily accessible for study. The basis of success is an adequate filing system which may necessitate a considerable amount of clerical work, but the results obtained will give knowledge that can be obtained by no other method.

The practical details will be described as they were carried out in my own department, but others may find that they could be modified to meet their own requirements.

Accuracy of case histories

It is essential that the history, the account of the physical signs, laboratory, radiological and other reports be accurate. In private practice and probably in many smaller hospitals they will be compiled by the surgeon himself. In most teaching hospitals this work will be undertaken by the student and the registrar, but it must be most carefully supervised by the surgeon. It is convenient to keep all notes clipped together in a receptacle in the ward or nearby so that they are kept clean and are not mislaid. A detailed note of the operation is added with all the pathological findings, and later notes from time to time of the post-operative progress. The family doctor is, of course, informed of the operative findings.

Surgeon's responsibility

When the patient leaves for home a final note of his condition is made, and all notes are gummed together at the margins. On the front page is entered

Clinical record

his name, age and address, the dates of his entry and leaving the hospital, the family doctor's name and address, and complete headings of the diagnosis and operative steps. These may be numerous: for example (1) old duodenal ulcer, (2) old perforation of peptic ulcer, (3) old posterior gastro-enterostomy, (4) gastro-jejunal ulcer, (5) severe haematemesis, (6) partial gastrectomy (Polya), (7) small post-operative pulmonary embolus. The completed notes are then sent to the follow-up department where they are filed alphabetically and indexed under all the headings. It is this step which entails considerable clerical work, but from it alone can the patient's notes be immediately located and the figures and results of any of the conditions listed be readily investigated.

Arrangements for follow-up

At the time of leaving, the patient is given by the ward sister a printed card, which states the date and time of his next examination, and a note of this date is pencilled on the front page of his bound notes. The appointment is arranged for two or three weeks ahead to allow for his convalescence.

A regular session either morning or afternoon of one day weekly must be devoted to the follow-up department. In order to ensure the attendance of the patients who are expected on any day a postcard is sent four days beforehand to remind them of the date and time.

Examination

Before the session commences the secretary collects the notes of the patients due for examination from the files. The patients are seen in turn, their tale is noted, any necessary examination is made, treatment is ordered and the results are entered in the old notes. Finally they are told when they will be seen again. On the average about sixty patients can be seen in a morning.

Attendance-card system

The recording of these dates and freedom from error in communicating with the patients were made extremely simple. The patient's name and address was typed upon small cards. A narrow box was made to take these cards and was provided with guide cards for every week of the year. The card was dropped into the appropriate space, which might be one week, three weeks, three months or even one year ahead. The cards of the patients to whom postcards had to be sent were thus easily collected, and in this step was found to lie the whole secret of success. If the patient was merely told to return in six months or a year there was a strong probability that the visit would be forgotten, postponed or abandoned. With the system of regular reminders less than 2 per cent of cases remained untraced, and even if the patient did not return, reminders were sent every week up to six months. He was, of course, informed that should any trouble arise before his next visit was due he could come any follow-up day without a reminder card.

Notes remitted to ward

If a patient made bad progress or any other lesion developed, and his re-admission was found necessary, his notes were taken to the ward, kept in the ward receptacle until his admission and then continued. The gain in having one set of notes, which is a continuous record of the patient's whole hospital life, is inestimable. There is no longer a series of disconnected and repetitive records. In a large hospital the department is, of course, part of the surgical unit, so that if a patient is suddenly admitted as an emergency, the first assistant has easy access to the records.

Advantages to surgeon

The value of such a department to the surgeon is enormous. He can enjoy the comfortable feeling that all records are being kept accurately and that the progress of the patients is being carefully watched. The facts and figures of his

own cases are readily available and he can speak with absolute certainty and confidence of his own findings and results.

The benefits to the patient are equally marked. Perhaps the most remarkable finding was the willingness of those who were quite well to come up and report their progress. Working men would lose a half day's work although they had only to report that all was well. It was very exceptional for a patient not to attend, and if he found that it was impossible to do so he would write and suggest a later date. He soon recognized the value of post-operative control. He was no longer a hospital patient; he was a friend of the surgeon.

Patients' attitude

Today the importance of after-treatment and rehabilitation is widely recognized, and from such a department not only can medicines be prescribed and diet and work controlled, but, if any form of special treatment such as physiotherapy or post-operative radiotherapy for carcinoma be required, arrangements can be made for this to be given in the appropriate department and the results can be watched and recorded.

After-treatment

Its greatest value, however, lies in the power it gives to recognize and treat any subsequent disease in its earliest stages. Every patient realizes that he is a member of a special medical department, and even if his next visit is not due for three months he will have no hesitation in coming earlier if troubled with any untoward symptom. On several occasions women who have been operated upon for some other lesion such as gall-stones, gastric ulcer or appendicitis have sought advice for a subsequent carcinoma of the breast in its very earliest stage.

Early diagnosis of subsequent disease

A follow-up department provides the answer to two of the questions which are exercising the minds of medical men today. It is the keystone for the maintenance of positive health for the patient, and it should constitute an important element in the postgraduate training of the surgeon.

[References to other titles are given under After-care in the Index Volume.]

AFTER-CARE—METHODS AND VALUE OF MASSAGE

By W. J. GARDINER, M.B. (Toronto), M.R.C.P., F.R.C.P. (C).
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1. DEFINITION AND HISTORY

15.] The term, massage, signifies a group of manipulations which are performed upon the soft tissues of the body by means of the hands. It is one of the oldest methods of therapy known; but in spite of its antiquity, many members of the medical profession are still unaware of the proper manner in which it should be used in order to obtain beneficial results. The first record of its use was by the Chinese over 2,000 years ago. Subsequently it was prominent in the era of Arabian medicine and amongst the ancient Greeks. Along with medical practice in general, it declined during the Dark Ages. The modern era of massage begins with its revival by the French and later by the Swedes. Although the clinical value of massage has been known for many years, it was mainly during the present century that improved methods of physiological research have explained its rationale and placed its use on a scientific basis.

2. PHYSIOLOGY

General massage produces diuresis with increased excretion of nitrogen, inorganic phosphorus and sodium chloride. It may have either a sedative or a stimulating effect upon the nervous system depending upon the type of massage used. Local massage relieves pain and muscle spasm, and produces capillary dilatation with resulting increased blood-flow. It assists the venous circulation and the drainage of lymph. By exerting tension local massage may stretch connective tissue and help to break down adhesions. These effects are obtained by either reflex or mechanical action. Vasodilatation, relief of pain and muscle spasm, and the effect upon the nervous system are the results of reflex action. Mechanical action increases the venous and lymphatic flow or by exerting tension it stretches connective tissue.

3. MASSAGE MOVEMENTS

The manipulations employed in massage can be divided into three main movement groups: (1) stroking, (2) compression and (3) percussion.

(1) Stroking

(a) Superficial

These movements are slow, gentle and rhythmic and are used only to produce reflex action. They may be performed either in a centripetal or centrifugal direction. This type of stroking appears to be one of the simplest, but it is difficult to perform properly.

(b) Deep

Effleurage

This type of stroking is known as effleurage. It is deeper and firmer than superficial stroking, and is used to aid venous and lymphatic flow. Its direction should always be centripetal. The proximal segment of the limb should be treated first; the muscles must be relaxed and the extremity should be elevated to obtain the assistance of gravity.

(2) Compression

Pétrissage

Compression movements, known as pétrissage, consist of kneadings and frictions.

(a) Kneadings

These movements consist of grasping, rolling, wringing or lifting a part of a muscle or muscle group, and are performed with either one or both hands. The muscles must be relaxed and the stroke should not be heavy in order to avoid a reflex contraction of the muscles. Kneadings are employed with the object of improving venous and lymphatic circulation, to stretch retracted muscles and tendons and to stretch adhesions.

(b) Frictions

Friction movements are performed by pressing deeply, the hand and fingers then being moved in a circular direction. Generally the tips of the fingers and thumb are used, and a certain amount of rhythm should be imparted. Frictions are important in the treatment of the smaller parts such as the hands, feet and face. They are useful in freeing scars and adhesions and aid the absorption of local fluid.

(3) Percussion

Percussion movements, or tapôtement, are the heavier strokes. They consist of clapping, hacking, slapping, beating, tapping, vibrations and shakings. The immediate effect of percussion is blanching, which is due to vasoconstriction, and this is followed by vasodilatation. The percussion movements are rarely used for therapeutic purposes.

Combined with heat and exercises

Massage is but one of many physiotherapeutic agents and is rarely used alone. Preceded by the use of heat, its effectiveness is increased. It is frequently followed by active exercises. Massage is only a means to an end, i.e. restoration of function. It should never be used in such a manner as to impress the patient that massage alone is going to cure him. In many surgical cases the use of heat and massage will prepare the affected part so that subsequent active exercises are facilitated. It is the general custom today to delegate the

actual administration of massage to a qualified masseuse. There is no objection to this if the surgeon assumes certain responsibilities. He must provide the masseuse with a diagnosis of the patient's condition, and an outline of what is to be accomplished. The surgeon should have a sufficient knowledge of massage to enable him to prescribe the type of stroke to be used, the site of application and its duration. He should supervise the case in order to note progress and to order necessary changes in treatment from day to day.

Surgeon's responsibility

Duration

The average duration of massage treatment is from ten to twenty minutes daily. It is cumulative in effect, one treatment giving slight, but many treatments unmistakable, results. In the administration of massage certain general rules should be observed. It is necessary that the patient's muscles be relaxed and the affected part supported. Likewise the masseur should be in a relaxed and comfortable position. Sufficient clothing must be removed from the patient to provide adequate exposure of the part under treatment. Talcum powder or lubricants, such as olive oil or cocoa butter, are frequently applied to the skin in conjunction with massage. Massage should be started lightly, and its force gradually increased with a definite progression from day to day. Aggravation of symptoms is a definite sign that massage is harmful and calls for either discontinuance or modification.

Rules of administration

4. INDICATIONS FOR MASSAGE IN SURGICAL CONDITIONS

Recent injuries

There are many indications for the use of massage in surgery, mainly in the treatment of recent injuries and fractures. In cases of contusions of the muscles massage should be withheld for twenty-four hours or until danger of further haemorrhage has passed. Effleurage should then be employed, gradually working on to the site of injury. In sprains massage increases the circulation, and thus facilitates the normal process of repair of ligaments and other damaged tissues. Occasionally persistent traumatic oedema is found above and below a joint probably due to reflex action of the vasomotor system. In such cases, with the extremity in an elevated position, superficial stroking progressing to deep stroking and kneading will aid recovery from the swelling. Following reduction of dislocations, massage is indicated for the relief of pain and aiding the repair of articular and periarticular tissues. It can be usefully employed during the period of immobilization.

Fractures

The importance of massage in fracture cases has decreased with the advent of modern treatment, which comprises adequate reduction, fixation and function during the period of immobilization. This conforms to the increased use of unpadded plaster splints, minimal periods of immobilization and earlier use of active exercises. It must not be thought, however, that massage has no place in the treatment of fractures. It will be found extremely useful in the reduction of swelling preceding the application of a plaster cast, for example in the treatment of fractures of the tibia and fibula. During the period of treatment by extension fractures of the femur benefit by massage. In fractures of the surgical neck of the humerus treated by immobilization with sling and bandages, combined with active exercises of the pendulum type, massage is of value in the early stages by relieving pain and muscle spasm and aiding the removal of haemorrhagic extravasation. In spite of adequate reduction, fixation and early active exercises there are always some cases which show residual disabilities

Femur

Humerus

in the form of articular and periarticular adhesions and muscular atrophy. In these massage, in conjunction with other forms of physiotherapy, will speed recovery.

In injuries to the joints, resulting in synovitis or traumatic arthritis, massage is of value in relieving pain and encouraging absorption of fluid. In bursitis massage should not be used during the acute phase. As the inflammatory process subsides light stroking and effleurage to the adjacent tissues can be started. In the subacute and chronic types of bursitis massage can be applied directly to the bursa. In traumatic tenosynovitis massage is indicated in conjunction with heat and rest.

Bursitis

Traumatic tenosynovitis

Massage is of considerable value in the treatment of scar tissue, where it helps to prevent excessive scar formation by freeing scars from underlying tissues and by preventing deformity from contraction. Consequently, massage is an important adjunct to plastic surgery in the preparation of the part for operation by increasing the blood supply, as in the case of a pedicle flap, and in loosening contractures that take place under skin grafts. In amputations the routine use of early active exercises has decreased the necessity for massage. In some cases massage is of value in accustoming the stump to withstand handling and pressure. In recently healed stumps with adherent scars much can be accomplished with massage towards freeing the scar, improving the circulation and increasing the tolerance of the scar to trauma.

Scar tissue

Amputations

In manipulative surgery forceful movement of a stiff joint sometimes results in temporary pain and swelling. Massage relieves these symptoms and thus prepares the part for active exercises. In peripheral nerve lesions massage is helpful in treating the paralysed muscles, aiding in the nutrition of the muscles involved and retarding the onset of atrophy. Massage should be light as the flaccid muscles do not tolerate treatment which is too heavy or prolonged. In upper motor neurone lesions in which spasm is present light stroking movements assist in obtaining relaxation preceding active exercise. Massage is an important adjunct in the pre-operative and post-operative treatment of many types of congenital or acquired deformity. In the early stages of Volkmann's ischaemic contracture massage aids in the relief of swelling and later in the nutrition of the surviving, although damaged, muscles. One should commence with surface stroking gradually encroaching on the swollen and painful area, progressing in a few days' time to deep stroking and in later weeks to kneadings. Massage is employed in the treatment of many cases of back pain, particularly where injury has caused contusion or sprain of the soft tissues. In obliterative vascular diseases daily massage of the affected limbs, using an application of lanolin, is of value in the prevention of trophic skin changes.

Peripheral nerve lesions

Upper motor neurone lesions

Deformities

Back pain

Obliterative vascular diseases

On rare occasions the surgeon may be confronted with the necessity of administering massage directly to the heart. One method consists of inserting the hand into the upper abdominal cavity and compressing the heart between the diaphragm and the ribs. A more effective method is to insert the hand through an incision in the diaphragm into the thoracic cavity. The heart is grasped near the base of the ventricles and rhythmic kneading applied. Restoration of the heart beat is probably a reflex response to mechanical stimulation of the heart muscle.

Cardiac failure

5. CONTRA-INDICATIONS

During the stage of acute inflammation, in which the reaction is serous or fibrinous, massage frequently does more harm than good. If infection is present with suppuration massage is absolutely contra-indicated. Massage should not be used in the presence of recent haemorrhage or where there is the possibility of producing haemorrhage, as for example in cases of peptic ulcer. Massage is contra-indicated in malignant disease, tuberculosis and osteomyelitis. Massage should not be used in thrombophlebitis or venous thrombosis until all inflammation has subsided and the clot has become organized. It is contra-indicated in acute systemic infections, acute diseases of the skin and in gangrene. Massage is contra-indicated in advanced arteriosclerosis, aneurysms and nephritis. In the treatment of children and the aged massage should be used in modified form. Massage is contra-indicated merely to increase muscle strength when voluntary power is present. Massage does not increase the size and strength of muscles. To attain that object it cannot supplant volitional effort. It must be remembered that massage may also be contra-indicated from the psychological viewpoint. It has often been said that it is easier to rub a disability into a patient's mind than out of an extremity.

6. CONCLUSION

Massage is a therapeutic measure of considerable value. Its action is either reflex or mechanical. The effects of massage are relief of pain and muscle spasm, the increase of arterial, venous and lymphatic circulation and stretching of adhesions or contractures. The beneficial action of massage is obtained by its prescription and skilful application in cases in which indications for its use are present. It is combined with other forms of physical therapy in a planned programme where restoration of function is desired.

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[References to other titles are given under After-care in the Index Volume.]

AFTER-CARE—ON RETURN HOME

By LINDSEY W. BATTEN, M.B., M.R.C.P.
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16.] Operations, however complex and difficult, have, in the theatre, a deceptive aspect of simplicity. The patient, unconscious and concealed by mask and towels, has vanished; the field of operation alone is on view; the surgeon is applying mind and hand to the solution of a technical problem, to performing his immediate task like a good craftsman so as to leave the tissues and organs involved functionally efficient and as little damaged as possible. For this he needs an undivided mind and he neither can nor should allow any picture he can form of the patient's personality and surroundings at home or at work to occupy more than a corner of it. The anaesthetist is perhaps a little more concerned with the whole patient but his task too is technical and limited. If he can ensure a smooth and comfortable induction, a degree of relaxation suited to the operation, a well-timed and comfortable return to consciousness; if he leaves a patient undamaged by his anaesthetic and unaware of his experience in the theatre he has played his full part. The ward sister, house surgeon or the patient's doctor assisting may realize, with something of a shock, how the anaesthetic and the apparatus of asepsis combine to eliminate from the scene of operation the person for whom it is all being done, and convey the illusion that all present are engaged in a surgical exercise which they hope, there and then, to bring to a successful conclusion.

Actually the operation is, of course, only the second act of a drama, small or great, and applause should be reserved for the conclusion of the whole play when all the company can disperse.

There are two more acts to come: act III, the surgical puerperium—the post-operative phase in the hospital—and act IV, the return to home life.

Act I opens with the decision to operate and is occupied with planning and preparation, and it is here, immediately the decision is taken, that all four acts should be visualized and plotted as far as practicable and at least a synopsis given to the patient and his relatives. Their understanding and co-operation is an indispensable factor in the success of the undertaking.

"Telling the patient"

How much should be told, and in what detail, to patients and relatives must depend partly upon the condition requiring operation, partly upon their intelligence, outlook and degree of enlightenment in matters of anatomy and physiology, but unquestionably the common practice is to tell too little. This is especially true of hospitals, in which the tradition of secrecy, of regarding all patients as persons who cannot understand, do not wish to do so and would be terrified if they knew, still prevails to an astonishing degree. But even in private practice the ignorance of patients concerning what is to be or has been done for them by surgeons is sometimes almost complete, and while the hospital patient remarks of hospitals that of course they tell you nothing there, the private patient makes the same complaint of doctors as a class.

That it is hard to put technical matters into the vernacular, to explain even the simplest piece of surgery to one quite ignorant of anatomy, and that what we tell may be turned to our hurt is all true. That does not absolve us from

the duty of at least trying to explain to our patients what is to be done for them, what they may expect and how they can co-operate.

Fear of the unknown

The counterpart of our tradition of silence is their reluctance to ask, and it may be taken for granted that they almost always wish to know. Fear is a potent cause of trouble before, after and even during operation. Our worst fears are of the unknown, and though no doubt there are ordeals best unimagined until encountered, there would be less fear of surgery if the patient awaiting operation had a clearer picture of what lay before him. Anything that can be done to make him feel he has some active part to play and is not reduced to so much surgical material will greatly support his courage and is, after all, no more than the plain truth. But it is later, when the discipline of the hospital and, for the fortunate, of the convalescent home lies behind, when our patient has become a free agent and member of a household again, when direct medical and nursing guidance has ceased, that he and his family most need to know what has been done, how matters stand and what is to be expected. Often they are woefully ignorant.

The significance of surgical undertakings is misconceived by patients and relatives in several ways. A few operations are too lightly regarded; tonsillectomy is pressed for by many parents on the slenderest grounds, and circumcision with general anaesthesia is scarcely deemed to require a reason; some patients will positively court a laparotomy. But more usually the operation itself and the anaesthetic are unduly feared, the immediate consequences and post-operative risks are under-estimated, and the fitness of the patient to return to normal life is misjudged perhaps as often in the one direction as in the other.

Every operation except the most trivial is in some degree both an ordeal and an event for the patient and his family. Its date is long remembered, and it may be held responsible for alterations in health, physically quite unconnected with it, for many years, perhaps for the rest of the patient's life. It is therefore of the first importance to ensure that all concerned view the matter in just proportion and neither assume that a patient just recovered from a relatively slight operation should at once possess his full health and strength nor that after a more severe one the subject of it can never be the same again. The truth is that quite small operations, however well and skilfully conducted, do for a time appreciably reduce the patient's vitality and endurance while, on the other hand, the general effect of a surgical ordeal, however severe, apart from the direct anatomical and physiological consequences of what has been done, ought not to be permanent.

Misconceptions about "shock"

Anxious patients and sympathetic relatives are apt to set great store by "the shock of the operation", regarded not as a transient post-operative state but as a lasting phenomenon, a chronic disorder parallelled by the notorious "shell-shock" of World War I which, by its mere name, suggesting a recognized organic clinical entity, has spoiled so many lives. It is very tempting for the medical practitioner to accept this proffered diagnosis of "the shock" as a convenient explanation of all manner of vague ill health, and as a morbid state which imputes blame to none and calls for little but sympathy, indefinitely extended, by way of treatment. Once accepted, the diagnosis may become irrevocable. Neither those who made or consented to it nor anyone else can alter or remove it: "She never," it will be said, "has quite got over the

shock of the operation." If, therefore, to preserve or restore health, not merely to excise or repair, is the true aim of surgery it is vitally necessary that this baneful phrase should neither be presented to the patient nor accepted from him.

Importance of prognosis

Regarded positively all this means that the surgeon must give as early and as detailed a prognosis as he can, either to the patient or his relatives or, perhaps best of all, to his doctor, and that he must make it his business to answer questions, whether asked or implied. Much that must be left open before operation can be forecast or decided immediately after it, and more still by the time the patient goes home and then, at latest, he should be told how he may expect to feel in the next days, weeks or months, what he should or should not do and how soon he may take up his usual activities. If restrictions are to be imposed, the reasons should, if possible, be explained even though the patient may prefer a simple pontifical injunction.

Vague, sweeping, unreasoned instructions are especially deplorable. "Do not exert yourself in any way for six months (or three), but after that you may do what you like", "on no account neglect the bowels", "drink as much fluid as you possibly can", all lend themselves to obvious abuse and there are many others like them. Even,"plenty of good nourishing food and a change of air" may prove a less innocent prescription than it sounds. Unless directly told to use his judgment or to be guided by specified indications the average patient will follow "doctor's orders" blindly and literally, content to feel that his surgeon and not he is responsible for what may come of them. Details must be given. Certain questions arise after every operation. They concern rest, exercise—general and particular—going away or "change of air", return to school, to work or household duties, diet and medicinal or physical treatment.

In all these it is as important to say what may and should be done as what may not. A surgeon who secures union of a fracture in good position has bestowed on his patient great potential benefits, but they may all be lost either by using the limb or part too hard or too soon or, as is now well recognized, by using it too little or too late.

Over-anxiety

The lasting disability will, in both cases, be due to physical deformities or alterations in the injured part, but an almost equal disability can arise from permanent distrust or anxiety concerning an injured part which, by all applicable tests, appears mechanically perfect. This applies,in some degree, not only to broken bones but also to any organ or part of the body subjected to operation. Even if the diseased part has been completely removed a complex of anxieties not susceptible to surgical treatment may be erected on the vacant site. Therefore the patient should be directly told to do whatever he may safely and usefully do. If he cannot safely begin at once he should be given a date on which to start, or a graded programme of increasing activity.

Healed abdominal incisions are often regarded by patients with quite unnecessary respect, and if they are firmly united and safe from injury by muscular exertion they should be pronounced to be so in good set terms.

"Rest" should not be lightly prescribed without definition in terms of place, posture and duration. The detailed prescription should have regard to the age, personality and surroundings of the patient as well as to the operation from which he is recovering. The notion, for example, that a child of the hospital

class is rested by not attending school needs thorough revision, and to prescribe rest for a housewife, a doctor, or a minister of religion in their own homes is almost always absurd. A patient of middle age or over, or one overworked before the event and now recovering from a serious surgical illness, does need a period of idleness; but to sit and be bored or to sit and avoid boredom by too much eating, drinking and smoking is good for no one, and a prescription which will in fact have this effect should not be given.

Effects of idleness

Going away is, as already hinted, a necessary condition of rest for some kinds of patient, but "change of air" without qualification will not do. The question to be asked and answered is: "*From* what, *to* what, surroundings and manner of life is the patient to go?". There is as little sense in driving one who is happy and comfortable in his own home to the annoyances and respiratory infections of the average seaside hotel as in advising a doctor to remain at home and rest there. It is the immediate environment—the house, the rooms and their inhabitants—rather than the site and climate which should count for most. Where will the patient find happiness, congenial company, stimulating surroundings and satisfying though unexacting employment? If he or his medical attendant knows of such a place, there he should go, regardless of altitude, aspect and subsoil.

Importance of environment

Return to work

So also the date of return to work should depend less upon the character of the operation than upon that of the patient and of the work awaiting him and upon his age, surroundings and resources. It is wise to inquire in some detail what "return to work" will actually entail and whether "half duty" or "light duty" is practicable. The actual strains and stresses, physical, intellectual and emotional, implied in his occupation should be ascertained and weighed as far as possible against his estimated ability to stand up to them. Only thus can a right decision be reached.

Diet

The recent advances of nutritional science have encouraged a willing public to give to food a therapeutic priority impossible to justify by fact and reason. Unless the operation has been one which really demands a specific diet the patient should be advised to take reasonably proportioned mixed meals according to appetite, and to avoid "extras". Good cooking and attractive serving are less common, but not less important, than good and sufficient foodstuffs. The young and especially the old may be pestered by well-meaning relatives to eat too much, and should be protected from this annoyance as far as possible.

"After-treatment"

Patients find it hard to believe that some specific "after-treatment" is not a necessary sequel to every operation. Understandably they feel that it is our job to give them back full health, not theirs to regain it, and they will press for massage, electrical treatment, ray therapy, vitamin capsules and tonics. The surgeon, on the other hand, may feel that having done his job and done it well he can trust Nature and the patient to do the rest, and he may thus leave a still enfeebled patient without the guidance and help he may fairly expect to receive; or, believing that the proposed restoratives are harmless, though physically ineffective, and can be justified by the charge of "suggestion" they carry, the surgeon may prescribe or sanction all or any of them in uncertain doses or for an indefinite period. Neither course can be justified. There is a middle way between leaving our patient in the air, and supplying him with unnecessary crutches, hard or impossible to discard.

Physiotherapy

If physiotherapy will do physical good a limited course of it should be ordered in detail, giving the patient, whenever possible, an active part to play and stressing its importance. If anaemia, residual pain, sleeplessness, genuine constipation or nervous irritability need medicinal treatment it should be carefully prescribed; even tonics have their uses, though the line between stimulation and over-stimulation is narrow, and alcohol, judiciously employed, is often more useful than strychnine. But often enough there is no real indication for any of these remedies, and the patient must be gently but firmly weaned from his medicines, relieved of his slings and crutches, real or metaphorical, and, having been shown the road to health, must be persuaded to ascend it himself.

He has to understand that he both can and must persuade his reluctant nerves, muscles and viscera to perform their tasks; that food, rest and sleep, with proportionate exercise, alone can replenish his reservoirs of energy; that the sun is the best ray-therapist and natural foods, not overcooked, the best source of vitamins; that hills, fields, sea and moving air, active recreations, laughter and the love of friends are the best tonics. His money, his family's or the State's will be better spent in securing for him a fair share of these health restorers—as far as money can buy them—than on encapsuled or mechanical substitutes.

Details of advice

Some details of the advice to be given in certain types of case to patients going home from hospital, or to their relatives, may here be added. After minor operations done under local or light anaesthesia patients should be given suitable analgesics to be taken in time to forestall the onset of pain. If any changing of dressings is required, "when" and "how often" should be prescribed and needless meddling forbidden. If bleeding is likely or possible, patients should be instructed as to its control, significance or insignificance and what action to take. After incision of fingers or hand for pyogenic infections means should be devised for keeping the hand slung up, waking or sleeping, and detailed instructions given.

Late chest complications may occur in patients returning home after operations done under inhalation or high spinal anaesthesia. Such patients should continue for a set time at home the regimen of changing posture, breathing exercises and no smoking learnt and practised in hospital. Patients afraid of "straining" or bursting their healed abdominal wounds may gain confidence, and trust themselves to cough if supported by an elastic adhesive bandage across the belly. Early abdominal exercises are useful to the same type of patient.

In all these matters the essential is to put ourselves, as far as may be, in the patient's place, picturing if we can not only his home surroundings but also his outlook and state of mind and leaving nothing to chance.

[References to other titles are given under After-care in the Index Volume.]

AFTER-CARE—POST-OPERATIVE

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1. DEFINITION

17.] This article deals with the general management of patients who have been operated upon, and covers the period during which they remain in hospital. It is not concerned with the details of post-operative care of particular operations, or of operations on special regions of the body. These problems will be discussed in the appropriate articles. It does not deal with "rehabilitation" or "re-abling". Nor does it deal with post-anaesthetic complications and management, which are considered elsewhere.

2. GENERAL

(1) Transport to ward from theatre

Protection from cold

It is important that every care be taken to see that the unconscious or only partly conscious patient, with protective reflexes absent or sluggish, should not be exposed to unnecessary cold and should not be roughly handled.

It is not enough to cover him with blankets. It is equally necessary to see that there is a folded blanket between him and the stretcher on which he is carried to the ward.

He should be accompanied to the ward by a nurse whose duty it is to see that the covering blankets are not disturbed, that there is no undue delay on the way and that, if movement should be impeded, he is protected as far as possible from cold winds.

Transfer from the stretcher to the bed should be done as gently as possible, and any rolling that may be necessary should be done with the minimum of disturbance.

The patient should not be covered by such a weight of blankets as to impede his breathing; warmth should be provided by hot bottles rather than by weight. The dangers of hot bottles should be ever present in the mind of the surgeon who is working in unfamiliar surroundings or with inexperienced assistants or nurses. If he is wise, he himself will superintend (tactfully) the installation of his patient in bed on the return from the operating theatre. In practice, the anaesthetist often relieves the surgeon of this duty, since his responsibility for seeing that the patient is settled in bed in such a position that breathing is free, and that there is no risk of inhalation of vomitus or blood, is equal to, or greater than, the surgeon's. The details of this post-anaesthetic care will be found in the section on Anaesthetics on page 250.

Hot bottles

Anaesthetist's duty

(2) Treatment of shock

When the patient is settled in bed, special measures for combating shock (if necessary, and if they have not already been instituted in the operating theatre) should now be undertaken. Unless the need for these procedures is very urgent, it is wiser not to be too active at once. A period of complete freedom from interference of any sort is often found to be of the greatest value. Intravenous or rectal infusions, hypodermic injections, etc., should be prepared at a distance and outside the screens surrounding the bed. When everything is prepared, they should be brought to the bedside and set up or given with the least possible noise or disturbance. There is no better gauge of the efficiency of a house surgeon or a surgical ward-sister than the amount of fuss that is associated with post-operative treatment.

Infusions and injections

3. IMMEDIATE POST-OPERATIVE PERIOD

(1) Post-operative pain and restlessness

With modern anaesthetic agents and the judicious combination of pre-operative medication with them, pain and restlessness in the immediate post-operative period have been greatly diminished. It is quite usual for patients to pass almost imperceptibly from the state of anaesthesia to that of sleep, and to have them wake up hours later with no recollection of the pre-anaesthetic or post-anaesthetic stages. Where, however, it is anticipated that the patient may be unduly restless on emerging from the effects of the anaesthetic—this may be because pre-operative medication was impossible or unnecessary, or because of the nervous temperament or alcoholic habits of the patient—it is a good plan to give aspirin and potassium bromide per rectum before consciousness is regained. This will often ensure a smooth and peaceful transition from anaesthesia to sleep. Twenty grains of aspirin with 40 grains of potassium bromide suspended in 8 fluid ounces of tragacanth and water is a usual dose for an adult.

Sedatives per rectum

(2) Relief of pain

When, however, real pain may be anticipated, it is better to give morphine

Drugs

or heroin as soon as consciousness is recovered. Morphine $\frac{1}{4}$ grain is an adequate dose for all but the most powerful individuals. It is more popular than heroin, but in the author's experience is less certain in its action, and more liable to induce nausea and vomiting. A comparable dose of heroin is $\frac{1}{6}$ grain of the hydrochloride. In the opinion of many, Omnopon $\frac{1}{3}$ grain is equally effective.

Whatever analgesic is given, it may be repeated at four-hourly or five-hourly intervals up to forty-eight hours after operation; but after the first twenty-four hours the surgeon should assure himself that the need is real. He should especially be on his guard against overlooking some painful or remediable complication in the wound such as excessive tension from retained blood or serum or unduly tight bandages or pressure from splints or plasters. When pain is so severe after forty-eight hours as to need morphine, it is incumbent on him to review the case carefully once more, and not to continue with the hypodermic treatment until he is completely satisfied that the cause of the continued pain cannot be removed or so much modified as to enable the patient to be comfortable with less potent analgesics. Usually it will be found that aspirin alone or aspirin, phenacetin and codeine will relieve what pain remains after twenty-four or forty-eight hours. When these fail, Nepenthe or Dilaudid (dihydromorphinone hydrochloride) will often succeed. Pethidine (Demerol) hypodermically is also of value, especially where the pain seems to be due to spasm.

Severe pain

When restlessness is marked, and especially when it borders on mania, soluble barbitone or intravenous paraldehyde are of great value, whereas opium derivatives either fail or even aggravate the trouble.

(3) Fluids

(a) Loss and replacement

Dryness of mouth and pharynx

Thirst is almost invariably experienced by patients as they begin to recover from the anaesthetic. There are two main reasons for this. First, dryness of the mouth and pharynx following the use of tubes and sponges by the anaesthetist, and the prolonged mouth breathing associated with loss of consciousness. This local cause for thirst is an unimportant if uncomfortable phenomenon, and may be relieved by frequent mouth washes (weak solutions of sodium bicarbonate to dissolve mucus) and by wiping the tongue and palate with solutions containing glycerin.

Body-fluid loss and its causes

Secondly, and far more important, is the thirst due to loss of body fluids. This comes about as follows:

(1) The limitation of drinking which is usual and justifiable before operation.

(2) Excessive loss of fluid from the lungs during and immediately after anaesthesia.

(3) Excessive loss of fluid by sweating during the operation. Some of this loss is inevitable, but it is frequently aggravated unnecessarily because the theatre is too hot or the patient is covered with too many blankets or mackintoshes during the operation, or because he is received into an overheated bed or room on his return from the theatre. The surgeon who notes that his patients are covered in sweat when the operation towels are removed should review the conditions in his theatre.

(4) Loss of fluids, i.e. blood or serum from the operation area.

(5) Shock.

(6) Post-anaesthetic vomiting.

Replacement of fluid

Whatever the cause of the loss of fluid, it is important that it should be made good without undue delay. It is obvious that, in the absence of special contra-indications and where the replacement of the fluid is not a matter of extreme urgency, the fluid is best taken by drinking. Patients as they recover from the anaesthetic should be encouraged to take frequent sips of water. It is not advisable to drink a large quantity at once, since this is liable to set up vomiting and so to defeat its own object.

(*b*) *Normal intake*

Whenever for any reason it is impossible for the patient to take sufficient or any fluid by mouth and he is therefore unable to regulate his fluid intake by *the appropriate sensations, it becomes the responsibility of the surgeon to see* that he gets an adequate amount of fluid by some other method. It is advisable, therefore, that the surgeon should have some general idea of the normal intake and output of fluid from the body.

Available fluid

It is estimated that the average adult under ordinary conditions has available somewhat over 2,000 cubic centimetres of fluid in the twenty-four hours. This includes water taken in food and drink and the water produced in the body by oxidation. He excretes in the same period (a) in the faeces 200 cubic centimetres, (b) by vaporization (lungs and skin) 500–1,000 cubic centimetres, (c) as urine 1,000–1,500 cubic centimetres.

Excretion

Quantity prescribed

The surgeon must see that approximately 3,000 cubic centimetres is given in each twenty-four hours. This amount should be appreciably greater when the fluid loss is increased (a) by heavy perspiration due to weather conditions, fever, hyperthyroidism, tetanus, etc., (b) by vomiting, diarrhoea or both, (c) by polyuria, for example in diabetes.

Assessment of adequacy

He can make a reasonable judgment as to the adequacy of the fluid intake by measuring the amount taken, and comparing it with the amount of urine *passed. When insufficient water is given, the excretion of urine is diminished* more markedly than the excretion by vaporization; therefore the amount of urine secreted each twenty-four hours is a good indicator. If the urinary output falls, the patient should be given more fluid until it rises again.

(*c*) *Methods of administration*

(i) *By mouth.*—There is little to say about this, the natural way of taking fluids. Patients should be restrained from drinking quickly, as this may precipitate vomiting. They should also be warned that too much iced water may bring on hiccough. When a patient has taken an adequate amount of fluid by mouth his thirst should be relieved. If it persists, the surgeon should assure himself that the fluid is passing along the alimentary canal and is not being retained in the stomach. If this be the case, acute dilatation of the stomach is imminent. The diagnosis is readily made by testing for a "succussion splash". When this complication is discovered, immediate drainage should be established by means of an indwelling small stomach tube.

(ii) *Per rectum.*—This should be the first substitute for normal drinking. The apparatus required is simple, and ordinary surgical cleanliness is all that is needed before using it. The fluid used can be any clean water at room temperature. Unless there are special indications, the addition of salt or glucose to the water is both unnecessary and undesirable.

Technique

A reservoir of one to two litres capacity is connected to a soft rubber catheter (about No. 8 English) by a suitable length of rubber tube. The flow through the tube is controlled by a screw clip and, at a lower level, a glass drip chamber. This latter should be so placed that with the catheter inserted in the rectum the chamber hangs not more than a foot above the level of the anus. This ensures that the column of water does not exert too much pressure on the rectum and so stimulate it to expel its contents. The rate of flow through the chamber should be about 60 drops per minute, which represents a delivery of about 120 cubic centimetres of water per hour.

Causes of failure

Sometimes the patient is unable to retain the fluid in the rectum. One frequent cause for this is because the drip chamber is too high and the column of fluid too heavy. Another common reason for failure is the presence of faeces in the rectum. A small enema will clear away the faecal lumps, and then the proctoclysis may be resumed. After about sixty to seventy-two hours the anus becomes sore, and the catheter causes a good deal of discomfort, so that it is frequently necessary to discontinue this method, and one of the other methods available must be tried.

(iii) *Intravenous.*—This is the method of choice whenever (a) the need for the fluid is urgent, (b) the exact composition of the fluid is important.

The article on "Acidosis" (*see* p. 53) should be consulted for a discussion on the choice of fluids for intravenous infusion and for a description of the technical details of the method.

Record of intake and output

Whatever the method or methods used, a record of the approximate amount of fluid taken and given should be kept, and this should be compared with a similar record of the amount of fluid excreted. The measurement of the output is necessarily very imperfect except for the urinary measurement, but careful reports by the nursing staff indicating the severity and frequency of sweating, and the consistency of the stools will help materially in deciding whether more or less fluid should be given.

(4) Diet

The patient is usually the best judge of his own diet. When he feels hungry, he should be allowed to eat, and unless he feels hungry he should not be pressed unduly to take food. This statement is generally true, but some patients are so determined to show that they are not upset by the operation that they will call for rich and indigestible food from bravado. On the other hand, some are so timorous and so determined to be invalids that they will take nothing. The surgeon and the nurse in charge must know how to restrain the former and encourage the latter.

Special care

When the operation has involved the abdominal and to a lesser extent the thoracic viscera, care in diet is essential. It is a sound rule to give water only for the first twelve hours, then liquids for the next twenty-four hours, and thereafter a light diet until the bowels have moved.

This is a general indication, and must be modified by the nature and severity of the operation and the general condition of the patient.

(5) Bowels

When an individual is suddenly confined to bed, and in addition has his normal habits upset by the pre-operative and post-operative régime, the accustomed rhythm of the intestinal movements is usually disturbed. The patient is made

conscious of this disturbance by painful colicky spasms which are called "wind" and which seem, in fact, to be associated with the movement or perhaps the lack of movement of pockets of air and other gases. Sometimes these pains can be relieved temporarily by the passage of a wide-bore tube per rectum, but usually they persist until the bowel is emptied by an enema or a purgative, or both. In general it may be said that no patient is really comfortable after operation until his bowels have acted.

Colic

It is usual to give an enema about forty-eight hours after operation, and to follow this by a dose of laxative medicine. The choice of medicament for the enema or washout is not a matter of great importance—a large amount (2 pints) of water or normal saline is useful, as is a small turpentine enema, or a soap, or an ox-bile, or a molasses enema.

As a laxative, cascara in liquid form with paraffin is usually effective. If it does not act and the patient is in much discomfort, castor oil in doses of ½ to 1 fluid ounce is drastic but certain in its action.

(6) Decubitus

The position of the patient in the immediate post-operative period should be on the side or back, with the head low to ensure that mucus from the pharynx and vomitus will flow out of the mouth and not be inhaled into the bronchi. As soon as the reflexes protecting the larynx are fully recovered, his position *should be dictated by his general condition and by the nature of the disease or* the operation. When he has regained consciousness and if there are no special contra-indications, he should lie on his back with the shoulders raised by several pillows, but there is no necessity to insist on this position, and in any event it should not be maintained if it adds to his discomfort. This is especially true during the night. Many patients need drugs to promote sleep, because the position in which they are expected to sleep is novel and uncomfortable. They should be encouraged and helped to find as soon as possible an accustomed and comfortable posture for sleeping.

Prevention of insufflation

Sleep

These remarks apply especially to cases recovering from abdominal operations. It is a sound plan with these patients to sit them up with the back supported by a special rest or by pillows and with a bolster supporting the thighs. An alternative method of achieving the same end is by raising the foot of the bed six inches; this has the added advantage of assisting the venous return from the lower limbs. This posture is comfortable, it is convenient for nursing purposes and, since it relaxes the anterior abdominal wall, it relieves the pain because the wound is not disturbed by movement. It also has the advantage that intestinal distension can occur without a great increase in intra-abdominal pressure. Just because it is so useful and so valuable, there is a tendency to confine the patient in this position unnecessarily long, and the surgeon should inquire into this matter when he pays his usual visit to the sick-room. It may be said that unless the man is very ill or unless there are special indications, for example drainage tubes, Fowler's position should not be maintained continuously for more than forty-eight hours.

Abdominal operations

(7) Period of confinement to bed

In general the patient should be allowed out of bed as soon as his condition makes it safe and as soon as he feels ready to get up. It is not possible to lay down any specific criteria which will cover the whole range of surgical

operations. The surgeon must consider (a) the general condition of the patient, (b) the particular disease for which the operation was performed, (c) the nature of the operation, and (d) lastly but, in this connexion, not at all least, the effect of added movement or strain upon the operation wound. This complex of factors concerned in the decision has tended to make the surgeons unnecessarily timid, so that on the whole patients are confined to bed too long.

4. POST-OPERATIVE COMPLICATIONS

The complications which are liable to occur after an operation, whatever its site or nature, are vomiting, hiccough, abdominal distension and wind, retention of urine, faecal impaction, unexplained pyrexia, venous thrombosis and pulmonary embolism. The major complications, bronchitis, pneumonia, collapse and heart failure, are dealt with in separate articles.

(1) Vomiting

Up to a few years ago, it was expected that all patients would vomit at least once or twice during recovery from anaesthesia and that a considerable number of them would vomit for about eighteen to twenty-four hours. Modern anaesthetic agents and modern methods of anaesthesia have made a great change in this respect. It is the exception rather than the rule for patients to vomit at all, and prolonged vomiting is rare. The initial vomit should be regarded as the effect of the anaesthetic, and if it is persistent or troublesome it may be controlled by giving the patient a good drink (10 fluid ounces) of water to which a teaspoonful of sodium bicarbonate has been added. This loosens the tenacious mucus in the stomach and oesophagus and may induce a copious vomit which expels the mucus.

Control

If this is not successful, the possibility that the vomiting is due to morphine or allied drugs should be considered. Very many patients when in the queasy post-anaesthetic stage vomit after morphine, and a considerable number are liable to do so even when in normal health. Both Omnopon and heroin are less likely to induce vomiting, and either may be substituted if pain is very severe, but it is better to substitute pethidine (Demerol) or one of the barbiturates. If these measures are unsuccessful, the stomach may be washed out with a solution of sodium bicarbonate 1 drachm to a pint through a small tube.

Post-operative vomiting may be unduly prolonged because the patient expects to vomit or always does vomit after an anaesthetic, or because the friends or even the nurses expect it. In these cases the surgeon or the nurse in charge may be able by a little quiet talk to cut short the sickness.

It must not be forgotten also that at times vomiting appears to be induced by lack of fluid and may be controlled by giving additional fluid by the rectum or intravenously. Again, at times a rusk or toast may be retained by a patient who has vomited all fluids taken.

Persistent vomiting

If vomiting persists for more than twenty-four hours, the surgeon must take care lest he be overlooking some reason other than the minor causes so far considered; the possibility that there may be acute dilatation of the stomach, intestinal obstruction, uraemia, etc., should always be borne in mind.

(2) Hiccough

Sometimes associated with post-operative vomiting, but more often an

unrelated phenomenon, is hiccough. When it occurs as a sequel to operations not involving the abdomen, it is usually a minor discomfort, relieved by carminatives and homely manoeuvres such as holding the breath. Pethidine (Demerol) is of great value—one injection usually sufficing to banish the hiccough completely. It must not be forgotten that it may be a manifestation of uraemia.

Control

Hiccough as a complication of abdominal operations may be an early manifestation of acute dilatation of the stomach, of ileus and of general peritonitis, and the wise surgeon will regard it as a serious complication until he has been able to satisfy himself that his fears are groundless.

(3) Abdominal distension and wind

This complication has already been discussed when considering the regulation of the bowels in the immediate post-operative period (*see* p. 134). It gives rise to very serious discomfort in many cases, but is usually completely cured once the bowels have moved. It often happens, however, that the pain and discomfort are very troublesome before the surgeon considers that it is advisable to give a purge or an enema. Heat in the form of fomentations or an electric pad may give some relief. A rectal tube may help. The only drugs that are effective are the derivatives of opium.

Control

(4) Retention of urine

After abdominal and perineal operations especially, many patients have some difficulty in micturating for the first time. Men are much more liable to this trouble than women. It appears to be due to a number of different factors.

Causes

Diminished secretion of urine, because of a small intake and an increased output by the lungs and the skin, leads to so gradual a filling of the bladder that the emptying reflex is not set in motion until the bladder is so full that this is itself an obstacle to micturition. The unusual position in bed and the difficulty in movement are additional factors. The association of micturition with movement of the anus and fear of the consequent pain is probably one reason why the trouble is particularly common after operations for haemorrhoids. The author is under the impression that this complication has been less frequent after haemorrhoidectomy since he began to use Proctocaine injections as part of the operative technique.

In women

The complication in men is not likely to be overlooked, but in women it may remain hidden because the patient may pass a little urine without emptying the bladder and so imperceptibly retain a large quantity. Indeed, the nurse may report that the patient has frequency or incontinence. Such a report should always be investigated carefully.

Treatment

The treatment is by stimulation of the external genitals and hypogastrium by alternate heat and cold, best applied by moist towels; by a change of position including standing or sitting on a commode; by an injection of acetylcholine; and, as the last resort, by catheterization (with full aseptic precautions).

Persistent retention

In the great majority of cases, the trouble is only with the first act after operation, but in a minority it persists for several days. In these cases, it is a good plan to make the urine acid with acid sodium phosphate, and to give hexamine which—whatever other effects it may have—makes the urine more irritating to the bladder. In the persistent cases, the possibility of organic disease, such as prostatic enlargement or derangement of the nervous control

of the bladder, must not be overlooked; nor in the early cases must the possibility of suppression of urinary secretion be forgotten.

(5) Faecal impaction or retention

When it is reported during the first week or two after operation that a patient, especially an elderly one, is suffering from diarrhoea, a rectal examination should always be made. The diarrhoea is frequently "spurious", and the trouble is a hard faecal mass that the rectum is unable to grasp and extrude.

(6) Pyrexia

Normal

Some pyrexia is normal during the first two or three days after operation. It should not be higher than 101° F. and the pulse is usually raised to correspond. It may be expected to fall by lysis and to be almost normal by the third or fourth day. If the rise is very high (104° F.) and occurs within twelve hours of operation, there is grave suspicion that septicaemia has occurred.

Abnormal

It not infrequently happens that, after the initial pyrexia has subsided and there have been two or three days with normal temperature, it begins to rise again without any obvious symptoms or signs to give a clue to what is happening. Sometimes after causing anxiety for a week or more the temperature subsides and no explanation is forthcoming. More frequently, a quiet abscess appears in the wound and may even discharge before it has been recognized. Sometimes bacteriological examination of the urine shows that it is teeming with organisms.

(7) Thrombosis

One cause of obscure pyrexia is venous thrombosis. This complication is more common than is generally recognized. The clot begins in the deep veins of the lower limbs. The exact site of the initial clotting is uncertain, and it is probable that there are several common sites. Many observers think that the veins draining the calf muscles are more often affected than elsewhere, but there is ground for believing that the trouble may begin in the large veins of the pelvis or the thigh.

Pain in the calf is frequently the first symptom complained of. On examination the calf is found to be tender to palpation. At the same time a little evening pyrexia (99° F. or 100° F.) may be noted. The time of onset varies from the fourth to the twelfth day. In the great majority of cases nothing serious comes of this. In a small but appreciable number of cases the thrombosis spreads to the main veins of the limb. This change is characterized by swelling and oedema below the knee and marked tenderness not only in the calf but also along the course of the femoral vein. Sometimes it is associated with a further rise in temperature, much constitutional disturbance and severe pain. Less often the spread is insidious and without any gross subjective evidence. Only the increase in swelling marks the change.

Involvement of the deep veins is a serious complication, not only because the constitutional disturbance and pain delay the recovery of the patient from the causal operation, but because the persistent swelling and discomfort of the limb may lead to prolonged or even to permanent disability.

Thrombosis of the superficial veins of the thigh or leg is a less frequent and less important complication and, since the clotted veins cause marked local tenderness, it is not likely to be overlooked.

(*a*) *Prophylaxis*

Since the factors which give rise to thrombosis are obscure, an entirely rational prophylaxis is impossible. It is generally assumed that stagnation in the venous circulation below the knee is one important factor. It follows that movement and exercise of the legs within the limits imposed by being in bed, and by the nature of the operation, should be encouraged. Patients should be instructed to exercise the calf muscles several times a day. Some patients with marked bodily weakness or with poor morale may need the help of a masseuse, but massage should never be regarded as other than a very inferior substitute for active exercise. In addition to promoting free circulation by movement, attention should be paid also to the avoidance of any measure, such as constricting bandages, knee pillows and so on, which may impede the circulation.

(*b*) *Treatment*

When thrombosis has occurred or is suspected, the limb or the affected segment should be firmly bandaged. This relieves the pain and tenderness more effectively than any other measure, and enables the patient to continue to move the limb as before. A loosely applied zinc and starch bandage (Viscopaste) next the skin, with a firmly applied Elastoplast bandage outside, can be worn for a week or ten days without discomfort.

Thrombosis is not of itself a reason for confining the patient to bed. Only when the thrombosis is massive, and the pain, swelling and constitutional disturbance are marked should he be allowed to remain in bed. In the writer's experience recovery is more rapid when the patient is encouraged to move about. This is not to say that movement must be forced, but that the ordinary post-operative routine should be interfered with as little as possible.

When massive thrombosis has occurred bandages should be applied as above. In addition, the limb should be elevated on pillows or by slings. Evidence is accumulating that intravenous heparin has a remarkable effect in relieving the pain and tension. So striking is the effect at times that it seems that the clot is actually liquefied and dispersed. It may be that further experience with heparin will prove that we have a potent weapon for use against a very distressing complication.

(8) Pulmonary embolism

This complication must be considered to be a sequel to venous thrombosis, and in many cases there is a clear relationship between the two conditions. It must be admitted, however, that embolism in the lung frequently occurs without any clinical evidence of thrombosis elsewhere, and it is not always possible, even in the post-mortem room, to demonstrate the site of origin of an embolus.

Infarction occurs usually between the tenth and twenty-first post-operative days, but may occur much earlier and much later. The clinical manifestations vary from a sudden sharp pain in the chest with or without blood-stained sputum and pleural rub to all degrees of local consolidation of the lung, and to sudden and dramatic death of an apparently well patient. The more massive and therefore more serious and horrifying emboli are particularly liable to occur when the patient first gets out of bed. Many of them are derived from clots which have been loosely attached to the wall of the femoral or iliac

of the bladder, must not be overlooked; nor in the early cases must the possibility of suppression of urinary secretion be forgotten.

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AFTER-CARE—REMEDIAL AND OCCUPATIONAL THERAPY AND REHABILITATION

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1. OCCUPATIONAL THERAPY

(1) Definition

18.] Occupational therapy is a science devoted to the restoration of disturbed physical or mental function by the use of selected scientifically employed occupations under the supervision and prescription of a surgeon or physician acquainted with the principles and methods of occupational therapy, and applied by trained occupational therapists adequately trained in crafts and craft technique.

(2) Classification

Occupational therapy is divided into the following three classes:

(*a*) *Psychological*

(i) General.—This has a wide field of usefulness in general hospitals, remedial workshops, sanatoria for tuberculosis, children's hospitals, and especially in nervous and mental homes and institutions, where applied as diversional therapy it has proved of the greatest value in improving general mental activities and in relieving the monotony and introspection that hinder recovery.

(ii) Specific.—In this type of therapy, however, there is the definite remedial objective of aiding relaxation, diminishing the subconscious psychopathic trends and aiding the development of concentration and voluntary control. In surgical practice, general psychological methods are of value where

veins. So far as is known, early and active movement in bed is the best prophylactic.

Treatment for the minor emboli is purely symptomatic and, for the larger infarctions, by general medical measures with particular reference to the prevention of secondary infection of the damaged lung. It is probable that heparin may prove equally useful here as it promises to be in thrombosis elsewhere.

5. THE WOUND

In general it may be said of the wound, following a "clean" operation, that the less it is looked at the better. Provided that the dressing applied in the theatre has not been disturbed and that the patient is not complaining of severe and continuous pain, the wound should not be disturbed until the first stitches are ready for removal.

Types of stitch

The visible stitches are of two kinds. First, those designed to hold the full thickness of the tissues in apposition; secondly, those whose function is merely to hold the actual skin edges together. The first group, usually silk-worm gut, nylon, silk or fine wire, should be retained for eight to ten days. The second group, of fine thread or silk, or metal clips, should be removed after forty-eight or seventy-two hours. Much post-operative discomfort comes from the tiny ulcers in the skin which all stitches must cause. These ulcers become larger and more inflamed the longer the stitches are retained, and the greater the tightness with which they are tied. The surgeon who has sympathy with his patient will take care not to tie his stitches tightly, will remove any stitch as soon as it has accomplished its purpose, and will inspect his wounds personally about the seventh or eighth day, to see whether he can safely cut one or more stitches that may be causing undue discomfort.

Removal of stitches

Drainage

Drains inserted for serous or bloody discharges can usually be removed at the end of forty-eight hours. Their presence carries a risk of secondary infection entering the wound; therefore they should not be retained, save in exceptional cases, for more than seventy-two hours. Extra precautions to prevent secondary infection should always be taken when dressing a wound with a drain in it.

When the function of the drain is to facilitate the escape of pus no time limit is generally applicable. Each case must be judged on its merits. The surgeon must consider the amount of discharge, the nature of the infection, the character of the cavity being drained (i.e. whether it has soft easily apposed surfaces or rigid walls likely to be brought together only by slow granulation), the change in the general condition of the patient, etc. He has two general principles to help him. First, that healing and resolution are delayed by retaining the drain too long. Secondly, that the opening into a suppurating cavity must be kept patent until the cavity is almost obliterated.

The risk of damage to vessels in close proximity to the wound track must not be forgotten. Secondary haemorrhage from erosion has occurred on many occasions. Whenever this complication is to be feared, a soft drain should be substituted for the usual semi-rigid tube as soon as possible.

[References to other titles are given under After-care in the Index Volume.]

(b) A therapy aimed at the increase of muscle power to the normal, demanded by the work when the man renews his employment, with an increase of range of movement of stiff joints.

(c) A therapy founded on the view that the best form of work therapy is to have the man exercise with the tools to which he is accustomed. No new technique, then, has to be taught, and the proper muscles are exercised, and the patient can himself recognize his progress and suggest the time to return to work.

(d) A clinic is most satisfactory with physiotherapy and occupational therapy departments, with the therapists of both groups in constant co-operation."

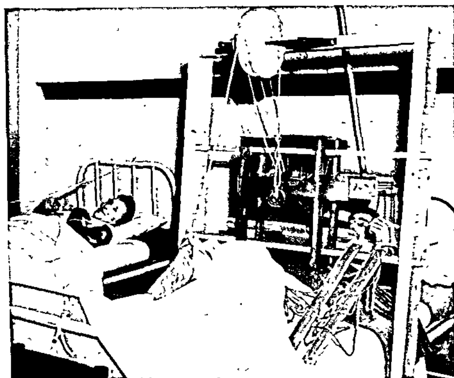


FIG. 50.—This man has to have work that will use his right arm and right leg in bed. This overhead loom was constructed so that one heddle is operated by his right leg and the other heddles and weaving done with his right arm.

Naturally, in addition to the specific physical treatment, the general principles of psychological and general physical occupational therapy require great consideration.

2. TREATMENT OF FRACTURES AND DISLOCATIONS

(1) Indications

The main indications for the treatment of muscle and joint malfunction may be considered from several standpoints. The joints and muscles above the mobilized region should have physiotherapy and remedial exercises from the commencement. Shortly afterwards occupational therapy should be added. The objective is to keep these muscles and joints in their normal state and

convalescence from injury will be prolonged, in spinal cases where permanent disability is unavoidable and for the general morale of the hospital ward.

Naturally, specific psychological occupational therapy is required where nervous and psychotic conditions appear during convalescence following the physical injuries.

(*b*) *Physical*

(i) General.—Apart from the treatment of local injury, it is frequently necessary to order forms of exercise which will energize the body as a whole, promote general good health and improve the general musculature and the function of the joints and nerves.

While remedial gymnastics and recreational exercises take preliminary care of these requirements, diversional and recreational occupational therapy have the great advantage that they retain the interest of the patient, and the treatment then can be continued over a longer period of time each day.

(ii) Specific.—This is, *par excellence*, an orthopaedic science since it is concerned with the application of occupation to restore the functions of the muscles, joints and nerves to the condition most suitable for employment. It limits the period of incapacity and increases the speed of recovery.

The occupation carefully selected for each patient stimulates his mental processes, and increases the interest and desire and ability to perform physical movements.

Concentration on the craft work which is being produced allows the prescribed muscular and joint movements associated with the task to be largely performed subconsciously.

Painful activity of the injured structures is more easily neglected under this subconscious activity, than when remedial exercises are undertaken.

Defects in movements of trunk or limbs are aided in recovery by selected occupation, involving the direct use of the muscles and joints affected. On the other hand, movements of the entire limb, using both normal and injured muscles and joints, may lead to a more employable limb at the conclusion of the treatment.

Care must be taken in the treatment, so that strong muscles do not overpower weak muscles.

The final objective is to produce a limb that is most serviceable to the individual in his employment.

Immobile joints may be made more mobile by the use of occupational therapy.

Co-ordination in muscular action may be greatly improved.

The incapacity resulting from nerve injuries is most satisfactorily treated by craft work specifically selected for the nerve involved.

(*c*) *Industrial*

This is the name applied to the specific occupational therapy used for the rehabilitation of the injured workman in order to restore him, if possible, to his former employment or to some suitable vocation. Its objectives are well stated in a bulletin issued by the Ontario Compensation Board:

"(a) A therapy not fixed or inviolable but in a constant state of change, ready to devise and invent new forms or modifications of old, to suit an ever-new state of conditions.

(b) A therapy aimed at the increase of muscle power to the normal, demanded by the work when the man renews his employment, with an increase of range of movement of stiff joints.

(c) A therapy founded on the view that the best form of work therapy is to have the man exercise with the tools to which he is accustomed. No new technique, then, has to be taught, and the proper muscles are exercised, and the patient can himself recognize his progress and suggest the time to return to work.

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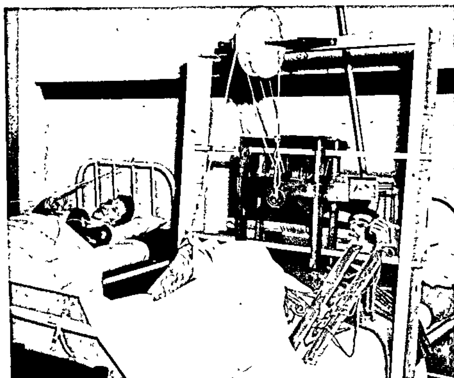


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The main indications for the treatment of muscle and joint malfunction may be considered from several standpoints. The joints and muscles above the mobilized region should have physiotherapy and remedial exercises from the commencement. Shortly afterwards occupational therapy should be added. The objective is to keep these muscles and joints in their normal state and

prevent the atrophy and fibrosis that may follow upon immobilization. While the surgeon usually immobilizes the muscles and joints related to the fracture there is evidence to show that specific tonic movements of these muscles are very advantageous and very rarely cause displacement of the fracture.

Grading of the muscular force to be exerted is of importance and such variation may be produced either by assistance from the operator, by voluntary activity of the patient, by increasing resistance—by methods such as choice of tools—or by special apparatus designed for the case.

Grading of the time for exercises and work is necessary, as is also the rate of muscle contraction in order to prevent exhaustion. Contractions of muscles and tendons may be treated by voluntary effort, by the use of tools or by passive stretching. Alternate contraction and relaxation rhythmically is far more useful than forceful movement as it permits more adequate circulation to the parts affected.

Full range of joint movement possible should be obtained.

(2) Crafts employed

The principal crafts, from the lightest to the heaviest, selected for remedial work are knotting, netting, basketry, weaving, fretwork, woodwork, metal-work, gardening, rail laying on sleepers, forestry and log splitting.

Remedial games are ping-pong, billiards, bowling, horseshoes, darts, ring-toss, foot-checkers.

While varied actions at different joint levels are obtained from almost any craft, yet the specified exercise required can be selected for any muscle defect. For movements of the fingers and thumbs and gripping exercises, wrist extension and flexion, one can select knotting, netting, basketry, different types of which elicit different muscle action. Pronation and supination are developed from basketry, seating, weaving and types of carpentry, while fret-work, planing and sawing re-establish elbow flexion and extension. Various shoulder exercises are obtained from basketry, weaving and carpentry, gradually advancing to heavy hammer work. Among the remedial games one easily recognizes the value of ping-pong, bowling and darts.

Similarly for hip, knee and ankle treatment there are many crafts; the bicycle saw, fretsaw, footpower weaving, potter's wheel, foot games and many other measures for which reference to a text-book is necessary.

It may be noted that psychologically it is often of benefit to have one man do the craft for an upper limb treatment while another with a leg disability produces the power.

3. TREATMENT OF STIFF KNEE JOINT

Treatment of stiff knee joint may be used to illustrate the measures used to restore joint mobility. Physiotherapy and remedial exercises are used in conjunction with occupational therapy.

(1) Bed patients

Grade I. Diversional only—wood carving, clay modelling, weaving and typing.

Grade II. Remedial—half-an-hour loom weaving (operated by flexion and extension of knee), half-an-hour knotting (same method) and three-quarter hour foot loom (with adjustments).

(2) Non weight-bearing

Grade I. Diversional—light carpentry, metalwork and table games.

Grade II. Remedial—one hour each foot loom with increasing resistance and light treadle grinder or lever saw (bilateral); half-an-hour sitting bowling.

Grade III. Remedial—one-quarter hour each heavy treadle saw (bilateral), potter's wheel, foot lever (injured leg) and light treadle grinder; half-an-hour either darts, ring-toss or floor-checkers.

(3) Weight-bearing (no caliper)

Grade I. Remedial—half-an-hour each bicycle saw (plywood), heavy treadle saw or potter's wheel, ring-toss, darts, horseshoes, benchwork or pottery (standing part time).

Grade II. Remedial—half-an-hour each bicycle saw (hardwood ½ inch) bicycle lathe, crosscut saw, gardening, ping-pong, bellringer and bowling.

Grade III. Remedial—half-an-hour each bicycle saw (hardwood ⅞ in.) bicycle lathe, painting in squat position, bellringer, bowling and ping-pong.

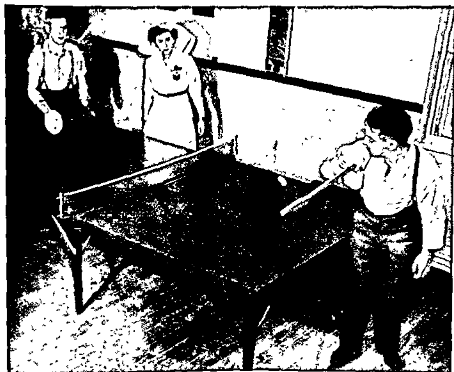


FIG. 51.—Patients with arm amputation and loss of right eye, playing ping-pong to strengthen stumps and improve movements before artificial hands are received.

4. TREATMENT OF AMPUTATIONS

Occupational therapy is required in the treatment of amputations and a description of the plan at Walter Read Hospital, which has specialized in amputations, will be helpful. Two stages are described, before and after fitting a prosthesis.

If the dominant limb has been amputated, then the question arises whether

writing should be immediately commenced, using the normal limb, or the amputated one, assisted by a leather cuff. While the latter method appears more satisfactory, yet where the amputation is at the shoulder or upper arm, or if the stump is unhealthy or painful, then the normal hand is used.

To develop manual dexterity with the untrained limb, one uses ping-pong and darts for general co-ordination and socialization. Inlaid rug weaving,



FIG. 52.—Gunshot wounds of the head resulting in right hemiplegia. Patient working on lathe to strengthen right arm and leg.

leather tooling, clay modelling and weaving give skill and confidence. After the prosthesis is fitted with a hand and hook, the former for show and the latter for work, the occupational workshop is used to teach the patient the use of his new arm and the prosthesis is tried out and checked. Amputation

checkers are the starting-point in treatment as they teach the patient how to use his arm and tools, and give the therapist an opportunity to make an adjustment of cords and straps.

Following this, as many activities are made use of as is possible, especially bilateral crafts, the hook hand being taught to be the helping hand. Cord

NERVE	*Slight active movement present*	*Active movement present, range limited*	Range and tolerance *good, fine co-ordination and* strength lacking
ULNAR	Pottery, clay modelling, scissors work, card weaving, warping, basketry, painting, checkers, pegcheckers	Bilateral carpentry (spokeshave, plane), scraper, metal shears, hammer work, writing, typing, knotting, netting, ping-pong, badminton, table hockey, shuffleboard, piano, golf	Heavy carpentry (hammer and wood-scraper), tether ball
MEDIAN	Pottery, clay modelling, weaving, leather lacing, carpentry (coping saw, spokeshave, drill hammer) scissors work, checkers, croquinole	Carpentry (saw, hammer, mallet, screwdriver), typing metal, ping-pong, quoits, badminton, bowling	Heavy carpentry
RADIAL	Clay modelling, painting, basketry, weaving, wallcheckers, quoits, croquinole	Bilateral carpentry (brace and bit, plane, screwdriver), ping-pong, horseshoes, bowling, darts	Heavy carpentry, darts
BRACHIAL PLEXUS	Carpentry (high bench with increasing levels), clay modelling, pottery, painting, weaving, wallcheckers, beanbags, quoits	Carpentry (high bench with increasing levels, brace and bit), painting at shoulder level, bowling, ping-pong	Heavy carpentry (above shoulder level)
POSTERIOR CORD	Light carpentry, bilateral tools, weaving, quoits, backhand, darts, checkers	Scissors work, shears work, painting, ping-pong, bowling	Painting, writing, badminton
PERONEAL	Bicycle-treadle saw, grinder, tether ball, horseshoes, quoits	Bicycle lathe, ping-pong, badminton	Treadle saw, potter's wheel, shuffleboard, darts
SCIATIC	Weaving foot loom, treadle grinder, quoits, darts, putting	Bicycle-treadle saw, potter's wheel, ping-pong, shuffleboard	Bicycle lathe and heavy saw, painting (low), badminton

knotting is the best medium, while heavy carpentry is an excellent final stage. The clip must be adjustable so that leather tools, paint brushes and different sizes of pens and pencils can be held, while with the pencil inverted, pages of a book or paper may be turned.

With double amputations use of knife and fork may be obtained by double cuffs, and ping-pong can be played most effectively with double paddles and bilateral skill developed. A bilateral amputee is now driving his car, flying his plane and breaking horses on his ranch.

For leg amputations physical therapy takes first place, teaching balancing exercises, walking, turning and the like. However, floor looms, bicycle saw, treadle printing presses and dancing classes are all useful in aiding rehabilitation.



FIG. 53.—Ulnar-nerve lesions. Playing checkers to improve grip and to extend fingers.

5. TREATMENT OF NERVE INJURIES

Nerve injuries require the selection of crafts applicable for the treatment of each individual nerve. Three main classes form the basis of planned treatment. Exercises according to the degree of injury following lesions of some of the principle nerves is indicated in the Table. (*See* p. 147.)

This description of the crafts and games used in nerve injuries gives the reader an idea of the wide variety of possibilities offered to avoid monotony and increase the interest of the patient.

6. TREATMENT OF HEAD INJURIES

Three classes of head injury may be considered for occupational treatment. (1) Head injury with mild concussion. (2) Head injury, more severe, and slight brain damage. (3) Severe brain injury with brain deficit.

In the first two groups the indication is to re-establish cerebral function and vasomotor control and alleviate headache and dizziness. In the last group the object is to help the surgeon to determine the work level of the individual.

Commencing with complete bed rest, advancing to sitting up at varying elevations in the ward, the patient is finally transferred to the shop, where he is gradually accustomed to activity.

He is started working at the lowest bench, and while there he does more than normal bending and perhaps an hour will cause return of the dizziness and headache. As he improves, the treatment is given twice daily, and the work made more difficult—perhaps making a pair of sawhorses, involving lifting 2 × 4's around, with heavy sawing and planing. As the work period is lengthened heavier tasks with more bending and rising are given; for instance, making a large cupboard with a good deal of cutting on the bicycle saw. Or he is started at gardening with hard digging, cutting and planting. A final advance is to ping-pong, or the heavier medicine ball thrown from person to person. Finally he is sent to physiotherapy for strenuous physical training leading, if progressive improvement is made, to discharge.

The same treatment is given to the third class, but the purpose is to ascertain the level of work he can reach.

Naturally there is a great field for the treatment of localized disturbance in function after injury of the brain, such as re-education of sensory loss, of the loss of position, and of astereognosis, while on the motor side we have to endeavour to teach the patient to regain the power of the limbs and improve co-ordination. For these objectives, the therapist can outline many different types of craft work which may be helpful in at least restoring some degree of improvement.

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[References to other titles are given under After-care in the Index Volume.]

AINHUM

See SURGERY IN THE TROPICS

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(c) Discharge—amount, mucoid, purulent or blood-stained.
(d) Fever—presence or absence.
(e) Previous attacks.
(f) Constitutional symptoms, e.g. rheumatism, neuritis.

(3) Larynx

(a) Hoarseness—continuous or intermittent; soreness on phonation.
(b) Voice—use or abuse.
(c) Difficulty in breathing—inspiratory or expiratory.
(d) Cough—whether spasmodic; character of sputum.

(4) General health

(a) Digestion, heart, lungs, kidneys, haemophilia.
(b) Habits as regards tobacco and alcohol.

2. EXAMINATION METHODS

The methods of examination used for the nose and throat are very similar to those employed in examining other parts of the body. Inspection of the face immediately demonstrates lack of function of the nose in the mouth breather. Deformities, either congenital or acquired, are quickly perceived. The nose being prominent and exposed frequently suffers trauma and the examiner should be on the look-out for the results of old fractures of nasal bones with displacement. A straight-edge of some sort helps in estimating the amount of deformity of the supporting bone or cartilage. The skin over the nose is closely attached to the underlying structures, and becomes tense and shiny, but not greatly swollen even when severe infection is present. Fronto-ethmoid infections often cause swelling of the soft tissues in the eyelids.

Palpation

Palpation readily demonstrates irregularities in the bony or cartilaginous structures of the nose or mouth.

The nasal cavities are dark and can be inspected only by means of reflected light.

Position of patient and light

The patient should be seated preferably on a straight-backed chair and face the surgeon. The source of light should be on the patient's left and on a level with the top of his head.

Left-handed surgeons or those with defective right eyes may prefer to sit on the patient's right side and have the source of light on the same side.

Reflected light

Reflected light will not penetrate far into the nose because of the direction of the nasal passages. In front, the passages pass upward and backward, while posteriorly the direction is backward and downward. The anterior part, being supported by cartilage, is movable and elastic, and can be lined up with the fixed bony posterior part by a speculum. The examiner will do well to remember where the cartilage ends and the bone begins for in so doing he will not insert his speculum too far and therefore unnecessarily hurt his patient.

Speculum

Normal appearances

The examiner should acquaint himself with the normal, smooth, pink, moist appearance of the nasal mucosa, and be able to see the septum medially, the inferior turbinate laterally, and the inferior meatus below. It is not always possible to see the middle turbinate and middle meatus unless a shrinking solution containing 3 per cent cocaine in 1 in 5,000 adrenaline hydrochloride is sprayed into the nose. This solution causes blanching of the mucous

AIR PASSAGES

By ANGUS A. CAMPBELL, M.B.

Professor of Otolaryngology, University of Toronto; Surgeon-in-Chief, Department of Otolaryngology, Toronto General Hospital

1. CASE-HISTORY TAKING

19.] Careful history taking is of the utmost importance in nose and throat practice, just as it is in general medicine.

The following should be inquired into:

(1) Nose

(a) Nasal obstruction—complete, partial, intermittent, continuous, bilateral, or alternating.

(b) Discharge—anterior, posterior, bilateral, watery, thick, mucoid, purulent, blood-stained, crusts, number of handkerchiefs used daily.

(c) Sneezing—time of day, frequency and whether aggravated by dust or fumes.

(d) Family history of allergies.

(e) Frequency of attacks and complications.

(f) Headaches—location and time of occurrence.

(g) Sense of smell—present, perverted or absent.

(h) Odour—noticed by patient himself, or others.

(2) Pharynx

(a) Mouth breathing—constant, intermittent, time of day or night, snoring.

(b) Soreness, or difficulty in swallowing, regurgitation of food, noise on swallowing.

(4) Nasopharynx

To examine the nasopharynx the light should be focused on the base of the uvula. A tongue depressor is gently inserted over the anterior two-thirds of the tongue, and a small post-nasal mirror ½ inch in diameter is slipped backwards behind the soft palate without touching the tongue or any of the pharyngeal tissues. The mirror is rotated upwards, and the light from the head mirror is reflected into the nasopharynx while the patient is instructed to breathe as if breathing through the nose. The whole nasopharynx cannot be seen at one time, but by rotating the mirror slightly from side to side various fields will be brought into view. The posterior margin of the septum is the landmark to identify first, and by slowly rotating his mirror the examiner may make out the posterior nares, the middle turbinates, the inferior turbinates, the fossae of Rosenmüller, the Eustachian cushions and tubes and any adenoid tissue present. The location and character of any secretion are also noted. In patients with sensitive throats a local anaesthetic, 5 per cent cocaine, should be swabbed on the palate and pharynx.

Structures visualized

Secretion

An instrument similar to a cystoscope and called a nasopharyngoscope is useful in difficult cases, but considerable skill is required to interpret what one sees.

Nasopharyngoscope

In children palpation with the right index finger may be carried out by having the child firmly held by an assistant. In young people a mass in the nasopharynx is usually adenoid but in older people a neoplasm is to be suspected.

Character of mass

(5) Larynx

The interior of the larynx can be seen only when illuminated, and this may be done either by direct illumination through a laryngoscope or by reflected light from a head mirror and laryngeal mirror. The latter is the more easily and more frequently used. The light from the head mirror is focused on the soft palate.

The patient's tongue is protruded and held by gauze between the surgeon's thumb and index finger, care being taken not to injure the tongue by pulling it too far down on the patient's incisor teeth. The back of a laryngeal mirror about one inch in diameter is pressed firmly against the soft palate and the patient is instructed to breathe quietly through his mouth. In the mirror the surgeon should see the base of the tongue, glosso-epiglottidean folds, valleculae, epiglottis, pyriform sinuses, ary-epiglottidean folds, false cords, true cords and two or three rings of the trachea.

Structures visualized

Occasionally gagging may be troublesome. Sometimes a few sips of cold water will be sufficient to prevent this but often swabbing the pharynx with a local anaesthetic such as 5 per cent cocaine may be required.

(6) Remote lesions

The mouth, throat and nose, in the order mentioned, are common sites for focal infections and these infections may be acute or chronic. The teeth, tonsils and adenoids should be carefully examined in all patients complaining of maxillary sinusitis, fatigue, headache, arthritis, neuritis, nephritis, phlebitis or iridocyclitis. Even when the teeth appear healthy, search should be made for pus pockets in the gums, and if large fillings or crowns be present, radiological examination of the teeth should be insisted on.

Focal infections

membrane as well as shrinking and will permit a much larger area of the nose to be examined. To palpate the nasal cavity a piece of cotton-wool on a probe answers very well.

Portable electrical instruments are very convenient for bedside work in the home or hospital, but when operative work is necessary reflected light from a head mirror is really essential.

(1) Transillumination

This is an additional helpful method in examining the frontal and maxillary sinuses, but as it has many fallacies it should be used in conjunction with other clinical findings in arriving at a diagnosis. The transilluminating lamp should be about six volts, covered by a shield except at the terminal end and controlled by a rheostat.

(2) Frontal and maxillary sinuses

...tal ...ses

The frontal sinuses are illuminated by having the patient in a dark room, placing the lamp on the floor of the sinus at about the junction of the middle and inner thirds and observing the bright areas above the supra-orbital ridge. Important information is gained from a clear sinus, but as frontal sinuses vary in size or may even be absent, little clinical importance can be attached to a dark one.

...illary ...ses

The maxillary sinuses may be transilluminated by placing a sterile glass tube over the lamp, putting the lamp in the patient's mouth and comparing the illuminated crescents under the lower eyelids. Pus, thickened walls or new growths cast a shadow while cysts and mucoceles are clear. The maxillary sinuses may be transilluminated from above downwards by placing the lamp over the inferior orbital margin, directing the light down and in, and looking for a brightened area on the hard palate.

...grams

Skiagrams are undoubtedly of value in the examination of the nasal accessory sinuses. They should always be made when operation is contemplated, but no operation should be performed on findings from them alone. Only good films should be deemed reliable.

...rpretation

The maxillary sinuses are easily visualized in an antero-posterior exposure. Pus, thickened walls, increased vascularity or new growths cause differences in the shadows. The frontal sinuses should be taken laterally as well as antero-posteriorly so that a good idea may be obtained of their depth. The ethmoids may be well visualized in an antero-posterior film and their density noted. A good idea of the geography of the sphenoids may be obtained by x-ray, but caution must be exercised in trying to interpret pathological changes in them as shown by this method of examination.

(3) Mouth and oropharynx

These regions may be inspected by reflected light, with an angular tongue depressor to control the tongue. The condition of the tongue, teeth and buccal mucosa is noted at this time. The tonsils, soft palate and posterior pharyngeal wall are carefully inspected. Pressure should be exerted on the tonsils to see whether any undue amount of exudate or secretion is present, but as this nearly always causes gagging it is wise to postpone this part of the examination till after the post-nasal space has been inspected.

swelling of a new growth or by severe oedema of the glottis. The operation may also be done to give rest to the larynx, drainage to the trachea in inflammatory conditions or as a preliminary to such operations as laryngo-fissure, laryngectomy or pharyngotomy. It should be done if possible before an emergency arises since it is much easier to do it during a quiet period.

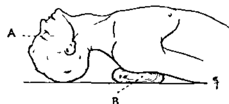


FIG. 54.—Tracheotomy. A: Head fully extended. B: Folded sheet under shoulders.

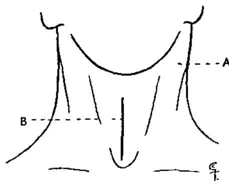


FIG. 55.—Incision for tracheotomy. A: Sternomastoid muscle. B: Vertical incision.

(2) Anaesthesia and preparation

Local anaesthesia is quite sufficient and much safer than a general anaesthetic.

A folded sheet is placed under the patient's shoulders and his head fully extended (*see* Fig. 54). The neck is infiltrated superficially with a solution of $\frac{1}{2}$ per cent Novocain and 1 in 200,000 adrenaline from the thyroid notch to the suprasternal notch. Two deep injections are made on either side of the trachea.

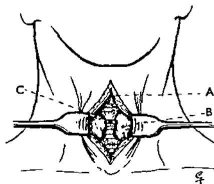


FIG. 56.—Tracheotomy. A: Skin and deep fascia retracted. B: Isthmus of thyroid tied off and separated. C: 2nd, 3rd and 4th tracheal rings.

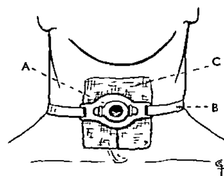


FIG. 57.—Tracheotomy tube in place. A: Tracheotomy tube. B: Gauze tapes tied around the neck. C: Gauze pad.

(3) Incision

Many general surgeons make a curved incision from side to side, as in the thyroid operation, but laryngologists prefer a vertical incision. The tip of the chin, thyroid notch and episternal notch are lined up and a vertical incision is made in the midline of the neck extending from above the cricoid cartilage to a short distance from the suprasternal notch (*see* Fig. 55).

A focus of infection should be suspected in the tonsils, if they show enlargement, redness of the anterior pillars, adhesions to the pillars, excessive amounts of caseous debris in the crypts, fluid pus, or retention abscesses, or if there is an enlarged cervical gland below the angle of the jaw. A focus of infection may occur in the nasal accessory sinuses, but this is less common than in the teeth or tonsils.

3. FOREIGN BODIES

These are frequently found in the nose and throat, especially in children, and may be almost anything. The commonest objects are buttons, beads, stones and coins, although fish bones are very common in the pharynx.

(1) Nose

Foreign bodies in the nose are accompanied by foul, unilateral discharge which is often blood-stained. They may remain in the nose for years, without serious symptoms. During this time they may become coated with calcareous deposits and are known as rhinoliths. They may be removed under a local anaesthetic to which has been added a shrinking solution such as adrenaline or ephedrine. They may be removed with forceps or, if they tend to slip backward, a hook is very useful. A plug in the post-nasal space will prevent objects from being displaced backward and being inhaled into the larynx. Parasites in the nose are not common in temperate climates, and may be successfully dealt with by drowning them in mineral oil. They can then be removed by blowing the nose or by suction.

Rhinoliths

(2) Pharynx

In the pharynx a splinter of bone or a fish bone may cause an abrasion as it passes along and symptoms of distress may be complained of for a day or two. They may lodge anywhere but most commonly they stick in the base of the tongue or tonsil. The patient can tell on which side the symptoms are, but has very little idea whether the body is high up or low down. Penetrating bodies may produce small abscesses. When found, foreign bodies in the pharynx are easily removed by means of forceps.

(3) Larynx

Small foreign bodies rarely stick in the larynx but large ones cause cough, hoarseness, aphonia, wheezing, stridor, cyanosis or dysphagia. They may be removed by the finger or by means of reflected light and long angular forceps. Occasionally direct laryngoscopy may be necessary for their removal. In children they may drop out if the child is held up by the feet. Emergency tracheotomy is seldom required.

4. TRACHEOTOMY

An obstruction to the airway situated above the upper part of the trachea can be relieved by tracheotomy. In some instances an intubation tube or a catheter may be inserted between the vocal cords as a life-saving measure.

(1) Indications

The operation should be performed immediately if asphyxia be threatened by a large foreign body closing the larynx, by a plug of mucus blocking the respiratory chink in a case of bilateral abductor paralysis, by the sudden

swelling of a new growth or by severe oedema of the glottis. The operation may also be done to give rest to the larynx, drainage to the trachea in inflammatory conditions or as a preliminary to such operations as laryngo-fissure, laryngectomy or pharyngotomy. It should be done if possible before an emergency arises since it is much easier to do it during a quiet period.

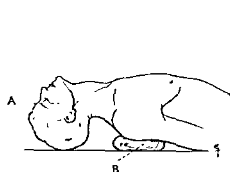


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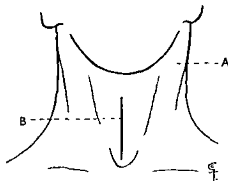


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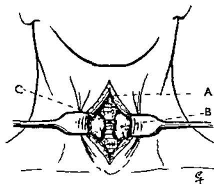


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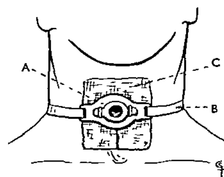


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ALLERGY

By The Late GEORGE W. BRAY, M.B., Ch.M. (Sydney), M.R.C.P.
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1. DEFINITION

20.] Allergy is defined as any specifically acquired alteration in the capacity of living tissue to react, resulting from exposure to an exciting agent, and is manifested on re-exposure to the same or an immunologically related agent.

Conditions with such an aetiology include asthma, hay-fever, vasomotor *rhinitis, urticaria, eczema and migraine.*

2. PATHOLOGY

All allergic manifestations show either a spasm of smooth muscle, an urticarial swelling of mucous membranes, or tissue infiltration with eosinophils, or any mixture of these.

Practically all allergic conditions come exclusively within the province of the physician, and the surgeon's interest is aroused only in cases of prolonged allergic reaction in the nose and in certain abdominal emergencies.

3. AETIOLOGY

(1) Specific allergens

Nasal conditions

As the nasal allergic conditions are of the most interest to the surgeon, they will be dealt with at length. The usual nasal specific sensitizing substances include the following:

(a) Inhalants: Feathers and down, orris root, animal emanations, tobacco, dusts (house or occupational); drugs (ipecacuanha, salicylates); insecticides, (pyrethrum, derris, nicotine); fungi (Alternaria, Aspergillus, Hormodendron or Cladosporium); osmyls or odours (scents, peeling new potatoes, passing a fish shop, cooking legumes, handling soap powders).

(b) Ingestants: foods (wheat, eggs, milk, chocolate, tomatoes, nuts); drugs (aspirin, iodides, quinine).

(c) Physical agents: cold, heat, light.

(d) Infectants: bacteria are rarely sensitizers.

(4) Technique

The skin and superficial fascia are divided and the infrahyoid muscles separated in the midline. The isthmus of the thyroid gland is identified, dissected free, clamped on either side, tied off securely and divided in the midline. The stumps of the thyroid isthmus are retracted laterally, and stitched out of the way, thereby exposing the second, third and fourth rings of the trachea (Fig. 56). An injection of 5 minims of a 5 per cent cocaine solution is made into the lumen of the trachea to prevent excessive coughing later when the trachea is opened. All bleeding must be stopped. An assistant fixes the cricoid cartilage with a firm hook while the operator removes a small oval piece of cartilage from the third ring anteriorly. Both the second and fourth rings are incised. Some coughing will take place at this time, and if this does not remove all the mucus and blood from the airway, suction should be employed. An introducer is placed in a suitable-sized tracheotomy tube and inserted into the trachea. The introducer is removed immediately leaving the tube in position. One or two stitches in the wound are sufficient. A square pad of gauze, three or four layers in thickness, is notched with scissors and placed over the wound, but under the outer flat portion of the tracheotomy tube. The tube is fastened in place by means of tapes tied around the neck (Fig. 57). Several layers of gauze moistened in normal saline solution are placed over the opening of the tube. This gauze should be changed frequently.

(5) After-care

The patient should be propped up in bed, encouraged to move about and allowed out of bed in a day or two. The inner tube should be changed every hour, and if there is much secretion suction through a flexible tube is very helpful. The whole tracheotomy tube must be removed and sterilized once a day. In favourable cases the tube may be removed in a short time, and the wound will close spontaneously in a few days.

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[References to other titles are given under Air Passages in the Index Volume. The subject of Air Passages is also dealt with under the heading of Allergy in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 303.]

the tip of the nose, or drawing the alae nasi apart by muscular movements of the lip upwards or to one side, separates the turbinals from the septum and promotes the easier passage of air.

Skin

(iv) Positive skin reactions.

Eosinophili

(v) The nasal smear test for eosinophils or a blood eosinophilia.

Skiagrams

(vi) Skiagrams of the sinuses with or without Lipiodol (Oleum Iodatum *U.S.P.* XII) instillation showing opacities due to thickened membrane.

Test

(vii) The immediate temporary response to adrenaline or Benzedrine (amphetamine).

6. TREATMENT

General hea

Removal of allergens

The treatment of the allergic nose should be primarily from the allergic aspect, even in the presence of obvious sinus infection. The patient's general health should be improved, encouraging adequate sleep and exercise; fatigue, emotion and chilling of the body's surface should be avoided; the basal metabolism may need raising by thyroid therapy; and any flatulent indigestion improved by hydrochloric acid administration. The specific irritants should be removed. Feathers, down and horsehair in the bedding should be replaced by air, spongy rubber, kapok, flock or vegetable down. Orris-root-free cosmetics should be used, and animals banished from the living-rooms and bedrooms. Sensitivities due to house and occupational dust, fungi, insecticides and pollens can be overcome with a course of desensitizing injections. Non-specific desensitization (bacterial vaccines, peptone, milk, sulphur, histaminase and autohaemotherapy) is of no constant value.

Symptomati treatment

Small doses of adrenaline hydrochloride solution subcutaneously or ephedrine by mouth night and morning will help to relieve symptoms, and ephedrine 1 per cent in spray or drops, or Benzedrine (amphetamine) or carbon dioxide gas inhaled may act beneficially locally.

Rhinologica procedures

Certain other rhinological procedures are mentioned only to be deprecated though they may produce slight temporary relief. Cauterization, either electrical or with chemicals (phenol or trichloracetic acid) aims at destroying areas of membrane so that further swelling of the sites cannot occur. Ionization induces sloughing of the old membrane, and the new membrane temporarily appears insensitive, but this soon becomes re-sensitized and so prolonged freedom is rare. Any constant beneficial effects of diathermy or radium treatments are also questionable.

Sinus infection

Sinus infection should be treated locally, if necessary by operation, in the same way as a similar infection should be treated in a non-allergic individual. Obstructive processes not responding to allergic therapy are best removed. Tonsillectomy does not relieve nasal allergy.

Aim of surgery

Conservatism is the keynote of treatment. Nasal surgery should aid the allergist to increase the defence mechanism of the nasal mucous membrane rather than aim at the removal of large areas of elaborate drainage systems. Any surgical therapy should follow allergic therapy and further allergic management follow the operation. In pollen-sensitive individuals operation should not take place during the summer months.

Drug idiosyncrasy

When local anaesthesia is necessary in an allergic patient, intracutaneous tests with the drug should be undertaken to ascertain that no hypersensitiveness

Non-specific allergens

The non-specific irritants include strong smells, bright lights, tobacco smoke, petrol or oil fumes, sulphur fumes from stoves, chlorine in pools or water.

(2) Nasal manifestations

Eosinophilia

Oedema

Mucous polyp

In the nose these allergens lead to an urticarial swelling of the membranes and tissue infiltration with eosinophils. As the nose has a central partition and corrugations, a small amount of swelling on the mucous membrane over each surface causes a great deal of blockage from apposition of the swollen membranes. As the area of the middle meatus and the middle turbinal is physiologically the inspiratory zone of the nose and therefore subject to the greatest irritation, and histologically the least equipped to deal with oedema, as it has only the slightest supporting stroma, the mucous membrane can easily prolapse. Nowadays mucous polyps are considered allergic in origin. Bacteria rarely penetrate an allergic membrane, so purely allergic noses rarely become infected in the absence of interference from without, and polypoid noses are even very resistant to infection.

4. CLINICAL PICTURE

Nasal symptoms

Predisposing causes

The nasal symptoms include a mixture of blockage, running and sneezing. In a person with an allergic predisposition, the first nasal discomfort usually follows an acute upper respiratory infection which lowers the patient's resistance whilst the inflamed membrane allows a more rapid absorption of inhaled particles; so the usual sensitizing factor is some common article in the environment at the time of the illness, either at home or at work, and not related to the type of the invading bacterium. Some patients date the onset from a nasal operation. In other cases a more prolonged lowering of resistance is necessary and the first symptoms appear after pregnancy, at the menopause, following fatigue, strenuous exertion or prolonged worry or emotional strain; in short, during states where the protective adrenaline secretion of the body is diminished or nearly exhausted. Allergic nasal symptoms are usually worse in the early mornings on waking or on getting out of bed, first because of prolonged contact with some irritant in the bedding or bedroom; secondly, the added physiological irritation on changing from warm air to cold, or when the feet touch cold objects (physical allergy); thirdly, possibly during rest the secretion of adrenaline is at the minimum.

Other symptoms

Besides the nasal symptoms mentioned, a chronic cough may develop from the mucoid post-nasal drip; or the resultant mouth breathing of cold, unfiltered air may convey irritant particles to the pharynx and later to the lungs, causing asthma; or headaches or pressure symptoms may follow blockage of the sinuses, and even a real migraine attack may supervene; and usually increasing deafness from blockage of the Eustachian tubes may result.

5. AIDS TO DIAGNOSIS

These include:

History

(i) A personal or family history of allergy.

Membranes

(ii) The typical pale, boggy, mucous membrane with a mucoid discharge, and the rarity of infection before surgical intervention.

Nose

(iii) The allergic salute and nose wrinkling; pressure inward and upward on

the tip of the nose, or drawing the alae nasi apart by muscular movements of the lip upwards or to one side, separates the turbinals from the septum and promotes the easier passage of air.

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6. TREATMENT

General health

The treatment of the allergic nose should be primarily from the allergic aspect, even in the presence of obvious sinus infection. The patient's general health should be improved, encouraging adequate sleep and exercise; fatigue, emotion and chilling of the body's surface should be avoided; the basal metabolism may need raising by thyroid therapy; and any flatulent indigestion improved by hydrochloric acid administration. The specific irritants should be removed. Feathers, down and horsehair in the bedding should be replaced by air, spongy rubber, kapok, flock or vegetable down. Orris-root-free cosmetics should be used, and animals banished from the living-rooms and bedrooms. Sensitivities due to house and occupational dust, fungi, insecticides and pollens can be overcome with a course of desensitizing injections. Non-specific desensitization (bacterial vaccines, peptone, milk, sulphur, histaminase and autohaemotherapy) is of no constant value.

Removal of allergens

Symptomatic treatment

Small doses of adrenaline hydrochloride solution subcutaneously or ephedrine by mouth night and morning will help to relieve symptoms, and ephedrine 1 per cent in spray or drops, or Benzedrine (amphetamine) or carbon dioxide gas inhaled may act beneficially locally.

Rhinological procedures

Certain other rhinological procedures are mentioned only to be deprecated though they may produce slight temporary relief. Cauterization, either electrical or with chemicals (phenol or trichloracetic acid) aims at destroying areas of membrane so that further swelling of the sites cannot occur. Ionization induces sloughing of the old membrane, and the new membrane temporarily appears insensitive, but this soon becomes re-sensitized and so prolonged freedom is rare. Any constant beneficial effects of diathermy or radium treatments are also questionable.

Sinus infection

Sinus infection should be treated locally, if necessary by operation, in the same way as a similar infection should be treated in a non-allergic individual. Obstructive processes not responding to allergic therapy are best removed. Tonsillectomy does not relieve nasal allergy.

Aim of surgery

Conservatism is the keynote of treatment. Nasal surgery should aid the allergist to increase the defence mechanism of the nasal mucous membrane rather than aim at the removal of large areas of elaborate drainage systems. Any surgical therapy should follow allergic therapy and further allergic management follow the operation. In pollen-sensitive individuals operation should not take place during the summer months.

Drug idiosyncrasy

When local anaesthesia is necessary in an allergic patient, intracutaneous tests with the drug should be undertaken to ascertain that no hypersensitiveness

exists, and in post-operative medication the astounding reactions that may follow aspirin and barbiturates should be recognized.

7. GASTRO-INTESTINAL CONDITIONS

(1) Diagnosis

Practically any acute abdominal emergency requiring surgical intervention may be simulated by an allergic reaction, and must always be considered when a bland diet, including particularly milk, wheat and egg, is followed by an increase of symptoms. To distinguish between organic disease such as peptic ulcer, appendicitis and cholecystitis, and allergy, the examiner must

Differential diagnosis

(a) inquire into a personal or family history of present or previous allergic diseases;

(b) administer adrenaline and observe if the symptoms subside;

(c) look for increased eosinophils in the blood or secretions.

Exploratory laparotomy

If these three investigations are negative submit the patient to exploratory laparotomy if abdominal pain is associated with fever, leucocytosis and muscle rigidity. Allergic forms of intestinal trouble are usually distinguished by the absence of diarrhoea.

(2) Clinical picture

Migraine

On occasions attacks of migraine or "sick stomach-ache" in childhood or adolescence are mistaken for acute appendicitis and the appendix removed. In childhood migraine takes the form of periodic attacks.

Signs and symptoms

(a) Rises of temperature, even up to 105° F., for a few hours very often in the early morning.

(b) Pallor, chilliness, tiredness, irritability of both mind and skin.

(c) Sick stomach-aches:

(i) Vague abdominal pain usually above the umbilicus, with no local tenderness.

(ii) From slight nausea to severe and repeated vomiting of even water, accentuated by motion (car and train sickness) or the upright position.

(iii) Bowels usually constipated (from allergic spasm of the intestinal smooth muscle or urticarial swelling of the lining mucous membrane or both, causing faecal retention); but may be loose or diarrhoeal, and only occasionally normal.

(iv) Associated alimentary tract symptoms including loss of appetite, foul breath and furred tongue.

(d) Cerebral symptoms, including faintness, dizziness, drowsiness and lapses of consciousness; occasionally headache, usually bilateral and frontal, only rarely unilateral.

(e) Nervous phenomena, including various eye symptoms (mistiness and blurring of vision, rarely certain palsies), numbness and tingling of limbs, loss of power or speech.

Age incidence of symptoms

In a given case only one of these five groups of symptoms may appear or predominate, but as the child grows older many of these symptoms are presented and may vary from attack to attack. The feverish turns are most prevalent from two to four years, the sick stomach-aches from four to eight years and the sick headaches towards puberty.

8. BRONCHIAL ASTHMA

Surgery has entered into the treatment of intractable bronchial asthma. Bronchoscopy to remove excessive tenacious secretion, and various forms of neurectomy (bilateral resection of the posterior pulmonary plexus, stellectomy) have been advocated by enthusiasts from time to time but such surgical procedures are rarely called for now.

Bronchoscopy

Neurectomy

Asthmatics are good surgical risks, the mortality rate in major operations being only 2 per cent. Pulmonary complications occur in about one case in eight, mostly post-operative pneumonia, but occasionally atelectasis. Many surgeons try to put off surgical procedures until the asthma has subsided. But anaesthesia causes immediate relaxation, and a combination of light anaesthesia with carbon dioxide and oxygen hyperventilation causes a minimal risk of pulmonary complications. Morphine should not be used in asthmatics for it abolishes the cough reflex, and if the spasm has subsided the mucous glands pour large amounts of sputum into the bronchial lumen and the patient drowns in his own sputum. Hence morphine is one of the leading causes of death in asthma. The best sedatives to use are pethidine (Demerol), Amytal, or Nembutal (Pentobarbital Sodicum *U.S.P.* XII).

Operative risk

Anaesthesia

Morphine

Sedatives

[*References to other titles are given under* Allergy *in the* Index Volume. *The subject of* Allergy *is also dealt with in the* British Encyclopaedia of Medical Practice (1936), Vol. 1, p. 302.]

AMOEBIASIS—AMOEBIC INFECTION OF INTESTINE (PATHOLOGY)

By The Late STUART McDONALD, M.D.
Professor of Pathology, St. Andrews University

1. DEFINITION

Description of parasite

21.] Intestinal amoebiasis results from invasion of the bowel wall by a protozoal parasite known as *Entamoeba histolytica.* This organism exists in two forms, vegetative (trophozoite) and cystic. In fresh wet unfixed faecal smears the living trophozoites appear as amoeboid structures, 20–30 μ in diameter, with a practically invisible nucleus and a translucent cytoplasm. This contains phagocytosed erythrocytes and the organism shows active motility. The presence of these two criteria is essential for identification. The nuclear structure is brought out by appropriate fixation and staining (*see Fig. 58*). The mature cysts, into which a proportion of the trophozoites develop, are usually 10–15 μ in diameter, and contain four nuclei. In addition, one or more cigar-shaped chromidial bodies are usually present.

Criteria for identification

2. AETIOLOGY

Carriers

Man is infected only as the result of ingesting cysts. According to Faust (1941) over 80 per cent of those infected become symptomless carriers and thus form a reservoir of infection far greater than that derived from clinical and convalescent cases. It is not generally realized that a considerable number of healthy persons in the United Kingdom, who have never been abroad, harbour *Ent. histolytica* cysts. Cysts are transmitted to other hosts by faecal contamination of water, ice and uncooked moist food and by the housefly. It is believed by some authorities that there is a "small race" of *Ent. histolytica* cysts which are non-infective to man; confirmation of this would materially alter the epidemiological outlook.

Epidemiology

3. MORBID ANATOMY

Initial invasion

Seat of election

Trophozoites develop from the ingested cysts and establish themselves in a superficial portion of the mucosa. The main areas affected are (1) the rectum and the pelvic colon, and (2) the caecum and the adjacent portion of the ascending colon. Biggam (1930) considers that invasion of the terminal part of the ileum may not be so rare as it is generally believed to be. The appendix may become secondarily involved.

Invasion of deeper tissues

By lysis of tissue and through their inherent powers of motility, trophozoites penetrate the submucosa and multiply by binary fission (*see* Fig. 59). At this

stage the lesion is represented by a minute slightly raised yellowish necrotic area with a surrounding hyperaemic zone. The characteristic feature of reaction to the parasite is a quiet necrosis without suppuration. Later, the trophozoites penetrate the muscularis mucosae, leaving a superficial area of necrosis which is now evident as an ulcer, often oval in shape and lying in the long axis of the gut. The damaged area is always larger than the presenting ulcer and thus assumes a flask shape, with rather irregular thick elevated edges (*see* Fig. 61). Progressive undermining leads to coalescence of the ulcers, usually along the circular folds (valvulae conniventes), through sloughing of the intervening epithelium which shows catarrhal change. By this time

Ulcer situated longitudinally



FIG 58.—*Entamoeba histolytica* in faeces. Nucleus shows a central karyosome and a condensed rim of chromatin at the periphery; numerous erythrocytes are seen within the cytoplasm. (Heidenhain's iron haematoxylin × 600.) (*T. C. Dodds.*)



FIG. 59.—Amoebic ulcer of colon. Area of submucosa showing four trophozoites lying in a clear lytic zone and surrounded by necrotic material. (Heidenhain's iron haematoxylin × 600.) (*T. C. Dodds.*)

the submucosa has become thickened as the result of oedema, capillary haemorrhage and round-cell infiltration.

Eventually, the muscularis mucosae is penetrated and trophozoites may be seen within its vascular channels some of which become thrombosed, thus aggravating the necrosis. The muscular coats of the bowel usually act as a more effective barrier but in some instances they also are invaded. This deep extension is aided by secondary pyogenic infection; recent reports suggest that penicillin therapy is a valuable preliminary to the specific treatment of intractable cases.

Ultimately, the greater part of the large intestine shows numerous deep ulcers, covered by a tenacious black slough; between the ulcers, zones of intact and sometimes slightly hypertrophic mucosa are almost invariably present (*see* Fig. 60). Reactive fibrosis is minimal, and much of the apparent thickening of the bowel wall is due to oedema. At any time the picture may be

Deep ulcers

Modification of picture

modified by a superadded attack of bacillary dysentery or a widespread mixed infection accompanied by gangrene.

Polypoid colitis

An unusual form of chronic intestinal amoebiasis in which ulceration is lacking has been described by Hines (1923). Here, the wall of the entire colon was



Fig. 60.—Colon showing typical chronic amoebiasis. Small discrete ulcers and large ragged erosions of the mucosa are present. (*T. C. Dodds.*)

thickened and studded with dirty grey nodules, which had been recognized radiologically. The causative organism was shown to be present in the affected tissues.

The intimate relationship of the trophozoites to the portal venules explains the incidence of amoebic hepatitis and liver abscess. In an occasional case

abscesses appear in other parts of the body. Actual perforation of the bowel wall is rare, but according to Wright (1941) localized slowly spreading peritonitis and ischio-rectal abscess are by no means uncommon. Severe melaena occurs in some cases. Secondary pyogenic infection not infrequently results in a rectal or caecal granulomatous mass which may give rise to obstructive symptoms.

Complications

4. SPECIAL AIDS TO DIAGNOSIS

Examination of faecal smears

The identification of trophozoites and cysts can be undertaken only by a specially trained protozoologist. In a suspected case of intestinal amoebiasis not less than six consecutive stools must be sent to the laboratory. The specimen is passed into a warm, dry bedpan; contamination with urine must be avoided. It is absolutely essential that the specimen be sent to the laboratory as soon as it is obtained; the trophozoites die quickly and when dead they cannot be identified. Since chronic bacillary dysentery may coexist, bacteriological examination of the specimen should be made as well.



FIG. 61.—Amoebic ulcer of colon showing undermining of epithelium and marked oedema of the submucosa. (Haematoxylin and eosin × 25.) (*T. C. Dodds.*)

Scrapings from suspected lesions should be obtained by proctoscope or by sigmoidoscope and should be emulsified in a small quantity of tepid normal saline. When caecal amoebiasis is suspected, Faust (1941) recommends saline purgation or a high retention enema of tepid normal saline given to the patient in the knee-elbow position, and the recovery of flecks of mucus from the watery evacuation. In rectal granulomas of amoebic origin, it is sometimes possible to discover the causal organism in fixed biopsy material.

Biopsy

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[Reference to other titles is given under Amoebiasis in the Index Volume. The subject of Amoebiasis is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 366.]

AMOEBIASIS – AMOEBIC INFECTIONS OF INTESTINE (SURGERY)

By C. NAUNTON MORGAN, F.R.C.S.
Assistant Surgeon, St. Bartholomew's Hospital; Surgeon, St. Mark's Hospital; Surgeon, Hospital for Tropical Diseases, London

1. GENERAL

Early lesions

22.] In the gastro-intestinal tract *Entamoeba histolytica* attacks the colon and rectum, rarely the terminal ileum. The early lesions, in contradistinction to those of bacillary dysentery, are situated in the submucosa, and invasion of the intestinal wall may lead to acute appendicitis, perforation, tumour or stricture formation or to haemorrhage. These complications are uncommon, but occur more frequently than in bacillary infection.

Surgical importance

Intestinal amoebiasis is of surgical importance for the following reasons:

(a) Its complications and sequelae may require surgical intervention or lead to misdiagnosis.

(b) Surgical treatment of abdominal or ano-rectal conditions, whether caused by amoebiasis or not, in the presence of this disease (which may be latent) must be avoided until specific treatment has been given, otherwise the result may be disastrous. When urgent operation is necessary, emetine injections must be commenced at once.

(c) Intestinal amoebiasis may be symptomless, the first indication of its presence being extra-intestinal, e.g. hepatic or pulmono-hepatic metastasis.

(d) Its manifestations are protean and may mimic other gastro-intestinal diseases such as gastritis, cholecystitis and recurrent appendicitis.

In endemic areas the tendency to treat as amoebiasis all vague gastro-intestinal symptoms without thorough investigation is, however, unjustified.

2. DIAGNOSIS

History and stools

A careful history and examination of the stools should prevent amoebiasis being overlooked as a cause of chronic and acute abdominal disease in patients who have been exposed at any time to amoebic infection. Sigmoidoscopy and repeated stool examination, when there is no urgency, are essential. Often

after several negative stools sigmoidoscopy will establish the diagnosis and the protozoon will be found on immediate microscopy from scrapings of the lesion. In strongly suspected cases, when amoebae cannot be found, culture may confirm the diagnosis.

Scrapings from lesions

Culture

(1) Sigmoidoscopic appearances

The lesions are usually minute and therefore easily missed; a magnifying attachment to the sigmoidoscope is very helpful. The appearances vary. Briefly, apart from the typical tiny pouting mouth-like ulcers seen after their white caps of muco-pus are wiped away, there may be large irregular angry ulcers with undermined edges, minute submucous haemorrhages, an area of inflamed hypertrophic granular or nodular mucous membrane with or without infiltration of the bowel wall, or a granuloma with or without ulceration.

Varied appearances

Associated lesions of bacillary dysentery will overshadow the more discrete areas of amoebic infection and sigmoidoscopy repeated about seven days after treatment with sulphaguanidine may reveal the dual nature of the infection. Occasionally discrete ulceration may be of bacillary origin; distinction between the two diseases may then be impossible and repeated examination is necessary after administration of emetine.

Amoebic and bacillary infection; sigmoidoscopy

(2) X-ray examination

Radiography following a barium meal or enema is as a rule of little help and there are no pathognomonic appearances. Distortion of a large segment or several areas of the colon together with evidence of perforation into other organs may suggest inflammatory disease.

Of limited value

In certain cases of amoebic tumour of the large intestine, x-ray investigation before and after treatment is of value.

3. COMPLICATIONS AND SEQUELAE

(1) Appendicitis and typhlitis

Acute appendicitis is the commonest intestinal complication of amoebiasis. When diagnosis is certain and especially if signs and symptoms suggest obstruction to the lumen of the appendix, immediate operation is indicated regardless of the presence of amoebiasis. If acute amoebic typhlitis alone is suspected and its diagnosis depends mainly upon the history, specific therapy and careful observation should be carried out.

Amoebic typhlitis

At operation, when both the caecum and appendix are found uniformly inflamed, the condition is likely to be amoebic or bacillary in origin. In these circumstances removal of the appendix is best avoided unless its lumen is obstructed, its blood supply in jeopardy or perforation likely. A completely normal appendix associated with an inflamed caecum should not be removed.

Associated typhlitis and appendicitis

Typhlitis with normal appendix

Following appendicectomy, an inflamed area in the caecal wall around the appendix stump should be oversewn, sulphonamide powder sprinkled locally, drainage established and emetine therapy commenced immediately.

When a mass can be palpated it may be impossible to distinguish between a pericaecal abscess, an appendix abscess or an amoebic granuloma; an abscess and a granuloma may both be present. In any case, the treatment is, at first, expectant, and emetine must be given if amoebiasis is proven or even suspected.

Palpable mass

Treatment

A mass resolving spontaneously without specific anti-amoebic treatment is unlikely to be of amoebic origin.

If indications for surgery arise, only simple drainage of an abscess with a minimal amount of interference should be permitted.

Recurrent and chronic appendicitis

Recurrent or chronic appendicitis may be a late sequel of intestinal amoebiasis, and after thorough investigation and medical treatment, appendicectomy may be necessary.

(2) Intestinal perforation—pericolic abscess

Fulminating type

A fulminating and even gangrenous form of amoebiasis of the intestine, though rare, is sometimes encountered and perforation and haemorrhage may cause death.

Common sites

The caecum and ascending colon are the commonest sites for perforation. Usually, when perforation is sudden, the signs and symptoms are classical, but in the occasional profoundly ill patient they may be insidious and the complication easily overlooked.

Treatment and prognosis

Early laparotomy, extraperitonealization if easy, or suture and isolation of the area with the omentum, together with adequate drainage, should be performed. Post-operatively specific therapy is urgent, and morphine and intravenous fluids are imperative. In general the prognosis is almost hopeless.

Pericolic abscess

When ulceration of the bowel wall is less rapid and adhesions have had time to form, perforation may occur into the pericolic tissues giving rise to a pericolic abscess with all the signs and symptoms of a localizing intraperitoneal collection of pus. A pericolic or perinephric abscess may form by direct spread of infection through the bowel wall without actual perforation of the intestine.

A localizing abscess must be kept under close observation and strict Ochsner and specific treatment instituted.

Extraperitoneal drainage

Drainage of the abscess is delayed when the condition of the patient and the size and progress of the abscess warrant it, so that simple drainage by an extraperitoneal approach through the loin may eventually be possible.

(3) Intestinal haemorrhage

Treatment

Fortunately this complication is very rare, occurring almost entirely in fulminating cases where prognosis, in any case, is grave. Treatment consists of giving blood by slow-drip transfusion and establishing early, under local anaesthesia, a caecostomy or appendicostomy for continuous colon lavage with Hazeline, half a drachm to the pint. Emetine, of course, must be administered at once, and all other measures adopted for the treatment of haemorrhage.

(4) Intestinal obstruction

Acute or chronic obstruction may be produced by amoebiasis, either as a result of a granulomatous tumour, an intussusception or very rarely a stricture.

Diffuse or multiple lesions

When the abdomen is open, inflammation with marked reddening and oedema at the site of the lesion, and thickening or acute inflammation of the remainder or of a portion of the colon, will suggest the inflammatory nature of the condition and the possibility of amoebiasis. The obstruction must be relieved by the simplest means and an anastomosis of any kind avoided in

the presence of active amoebic infection. The intestine should be handled with the greatest gentleness.

Adhesions in right hypochondrium

Very occasionally subacute obstruction occurs following adhesion of small intestine in the right hypochondrium associated with amoebic hepatitis. The adhesions should be left undisturbed and the obstruction treated by gastro-



FIG. 62.—Amoebic granuloma, showing *E. histolytica* inside a blood-vessel. (*Brit. med. J.*)

intestinal decompression with a Ryle's or Miller-Abbott tube. Fluid and electrolyte balance must be controlled by intravenous therapy.

Amoebiasis may exist for years

Amoebiasis may exist for many years before being diagnosed, so that a well-established lesion such as a large tumour or very rarely a stricture, may first bring the patient to the surgeon.

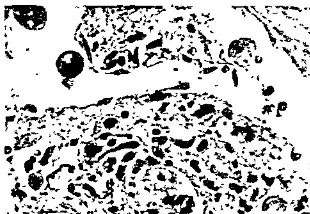


FIG. 63.—Higher magnification of area marked in Fig. 62, showing *E. histolytica* lying in a small vein. (*Brit. med. J.*)

(5) Amoebic granuloma (amoeboma)—cutaneous amoebiasis

Progressive amoebic invasion of the bowel wall with superadded secondary infection may lead to the formation of a granulomatous tumour. (*See* Figs. 62 and 63.) The inflammatory process eventually involves the surrounding

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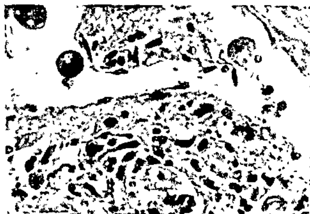


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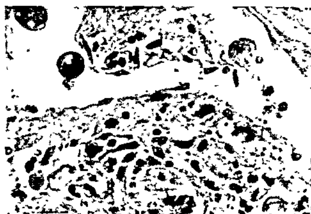


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Progressive amoebic invasion of the bowel wall with superadded secondary infection may lead to the formation of a granulomatous tumour. (*See* Figs. 62 and 63.) The inflammatory process eventually involves the surrounding

Indistinguishable from carcinoma

tissues, producing a hard fixed tumour, indistinguishable from a carcinoma. In the caecum it may be mistaken for hyperplastic tuberculosis or even actinomycosis. (*See* Fig. 64.)

Sites

The usual sites for such a granuloma are the caecum, recto-sigmoid junction and the rectum; occasionally two tumours may be present. As a rule the tumour is submucous and nodular, or occurs as a deeply indurated ulcer, though usually on palpation the bulk of the amoeboma is smooth.

Signs and symptoms

The signs and symptoms vary according to the site of the mass, and in general are those of a carcinoma—loss of weight, obstructive and dysenteric symptoms, and a filling defect on x-ray examination. Inflammation usually extends to the peritoneal surface of the bowel sooner than in the case of a carcinoma, so that there may be early evidence of local inflammation with pyrexia and polymorphonuclear leucocytosis.

Peritoneal involvement



Fig. 64.—Amoebic granuloma of caecum resembling malignant growth. (*By courtesy of Col. G. R. McRobert.*)

(*a*) *Diagnosis*

The history of previous amoebic dysentery, the isolation of amoebae from the stools or the presence of amoebic lesions seen on sigmoidoscopy will suggest an amoeboma, but it must be remembered that not only may carcinoma and amoebiasis coexist but that even with an established amoeboma there may be no other evidence of amoebic infection.

Amoeboma and carcinoma

Biopsy

When the lesion is within reach of the sigmoidoscope, the only sure method of diagnosis is biopsy. It is important to remove a good and representative piece for microscopy.

Test

The therapeutic test of emetine injections is of very great value, since, in most instances, the amoeboma dramatically melts away.

(*b*) *Cutaneous amoebiasis*

The occurrence of amoebic ulceration of the skin may be the first clue to the true nature of the tumour.

Ulceration may spread from an operation wound such as the site of an appendicectomy, caecostomy, colostomy or drainage of an abscess. In the anal canal amoebic fissures may appear.

The ulcer is shallow and has a sharply defined edge which may be irregular and undermined or sometimes markedly heaped up. Its base is yellowish, dirty and unhealthy, and there is usually little or no surrounding inflammatory reaction; its appearance is not unlike spreading post-operative gangrene. Following injections of emetine the ulceration miraculously fades away and the skin rapidly heals.

On very rare occasions when an amoeboma has reached an advanced stage, extensive fibrosis and destruction of the bowel wall will not allow resolution, in spite of emetine therapy. If a tumour does not entirely disappear following treatment, its removal may become necessary in order to restore the patient to health or because its nature is uncertain.

(6) Stricture

Incidence

Stricture of the rectum or colon is an extremely rare sequela and its amoebic origin may be difficult to prove. If amoebiasis is suspected, anti-amoebic treatment should be given, but as a rule the smooth resilient stricture will be unaffected and finally resection or short-circuit may become necessary.

Misinterpretation of spasm

Localized and persistent spasm of a portion of the colon visualized by x-ray may easily be mistaken for an actual stricture.

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AMOEBIASIS—LIVER ABSCESS AND PATHOLOGY OF AMOEBIASIS OTHER THAN INTESTINAL

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1. DEFINITION AND AETIOLOGY

23.] Secondary amoebiasis may be defined as invasion of the tissues by *Entamoeba histolytica* from a primary focus in the colon.

2. SURGICAL ANATOMY

Portal circulation

The portal venous blood flows in fairly well-defined currents, the blood draining from the caecum and upper half of the colon being directed mainly to the right side of the liver.

3. PATHOLOGY

Emboli and their course

Showers of emboli containing amoebae enter the radicles of the portal vein from the intestinal submucosa. Their fate in the liver depends upon the intensity of the invasion, the state of the hepatic defences and the institution of efficient treatment. A small invasion may be overcome by the liver cells with little or no clinical disturbance, but a heavier invading force gives rise to a generalized hepatitis with a cellular reaction around multiple foci of amoebae which produce cytolytic ferments. The reaction may result in resolution, in the

production of multiple minute necrotic areas followed by resolution, in the formation of multiple small abscesses or in the breakdown of one extensive area (generally in the upper part of the right lobe) to form a solitary liver abscess. At any stage natural defences may prevent further development. It is not unusual to find inspissated abscesses with calcified fibrous walls at necropsies in natives of the tropics.

Metastases

By invading the hepatic vein radicles, amoebae may reach the brain, testis and lung. The wall of a liver abscess has a layer of cellular infiltration at its periphery. Fibrosis occurs there in favourable circumstances. Vegetative amoebae lie deep in the wall of the abscess and are not found in the pus on aspiration, but may be demonstrated later after drainage has been established.

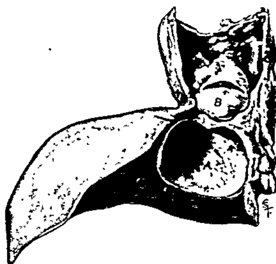


Fig. 65.—Fatal rupture of amoebic liver abscess into pericardium; (*a*) abscess cavity, (*b*) rupture into pericardium.

The pus is light chocolate or "anchovy sauce" in colour and in most cases is bacteriologically sterile. The abscess tends to cause adhesions to form to neighbouring organs. Rupture may occur into any of these—bronchi, pleura, peritoneum or pericardium (*see* Fig. 65) or through the anterior abdominal wall.

Adhesions and rupture

4. CLINICAL PICTURE

The condition occurs in persons who have resided in the tropics. A history of amoebic dysentery may or may not be obtainable. It is rare in young children and uncommon in women. During the preliminary stage of hepatitis the symptoms may vary from slight malaise, with mild epigastric discomfort, low pyrexia in the evening and persistent loss of weight, with pain or discomfort in the right shoulder, to severe prostration with acute pain in the upper abdomen, guarding of the recti abdominis and high temperature with rigors, sweating and vomiting.

Symptoms

The liver is tender and may be palpable several finger-breadths below the right costal margin. Restricted movement of the right side of the chest, dullness on percussion, and a pleural rub or crepitations at the right base are usual. With a large abscess there is local bulging of the liver with tenderness and oedema over the chest wall. Jaundice is rarely present.

5. DIAGNOSIS

(1) Special aids

Radiography

Ordinary liver-function tests are of little value. Radiography is of great assistance. Localized spasm or diminution in the normal excursion of the diaphragm, with haziness at the base of the right lung, suggest hepatitis. Deformity of the liver outline with localized bulging points to actual abscess formation.

Blood count

Fever without leucocytosis is almost certainly not due to hepatic amoebiasis, in which a leucocyte count of 12,000 to 30,000 is usual with a polymorph content of less than 80 per cent. If the polymorph count exceeds that figure secondary infection of the abscess may be suspected.

(2) Differential diagnosis

Febrile conditions

This includes a host of febrile conditions. Blood examination excludes malaria. *Escherichia coli* (*B. coli*) infection of the urinary tract not uncommonly coexists with intestinal amoebiasis and should be excluded as a cause of pyrexia with leucocytosis.

Cholecystitis

In cholecystitis tenderness is more localized, there is a history of flatulent dyspepsia and the polymorph count exceeds 80 per cent.

Jaundice

In infective hepatitis (epidemic jaundice) the liver is enlarged and tender, and fever is present, but even before obvious jaundice develops, bile derivatives can be detected in the urine. In portal pyaemia the patient is more acutely ill, is jaundiced and a primary focus is discoverable.

Test

Emetine dosage

The therapeutic test clinches the diagnosis. If the patient does not show marked improvement, with diminution in the size of the liver, loss of tenderness and fall in temperature and reduction in the leucocyte count after daily intramuscular injections of one grain of emetine hydrochloride for five days, the case is not one of early hepatic amoebiasis.

Any lump in the abdomen, movable or immovable, with or without pyrexia and even in the absence of leucocytosis, may be a hepatic abscess.

6. PROGNOSIS

The results of treatment of amoebic hepatitis by emetine obtained from a reputable firm are excellent, recovery being the rule. This is also true of liver abscess too small to require aspiration.

The replacement of open operation by aspiration and emetine has reduced the case mortality for large abscesses from 60 per cent to under 2 per cent, but in cases in which open operation is necessary in hot damp climates the prognosis depends upon the care exercised in dressing the wound. Sulphonamide powder and penicillin help to mitigate the former dread of fatal infection from without.

Asphyxia or aspiration pneumonia may result from rupture of a liver abscess into a bronchus, but in favourable circumstances the whole content of the abscess may be coughed out and, with prompt emetine therapy, complete recovery often occurs. Rupture into the pleura is amenable to aspiration and emetine. Severe shock is produced by intraperitoneal rupture, but recovery is usual if operation is undertaken within six hours.

7. TREATMENT

(1) Non-operative

Intramuscular injection of one grain of emetine hydrochloride daily for twelve days generally succeeds in removing the signs and symptoms of amoebic hepatitis, and of liver abscess not large enough to cause localized tenderness or marked deformity of the liver shadow. The patient should be confined to bed for three weeks. In addition to being a cardiac and nerve poison emetine causes local tissue necrosis; exceptional precautions must be taken to sterilize the syringe, needle and skin. A hot-water bottle applied afterwards greatly reduces complaints of pain following emetine injection. *Emetine*

(2) Operative

(*a*) *Indications*

Emetine without operation will in many cases remove all symptoms even if there is a large abscess, but relapse after a few months is common if the natural liver defences are left to deal with a large collection of pus. If much pus is suspected on account of persistent deformity of the liver shadow or if a demonstrable bulge remains, operation should be undertaken.

(*b*) *Aspiration*

Aspiration is the operation of choice. A Potain aspirator is most useful but a 100 cubic centimetre Record-type syringe with a three-way tap and nozzle is often more convenient.

Two important rules must be observed. (i) Do not attempt to explore or aspirate an inflamed liver until emetine has been administered for three days; otherwise fatal haemorrhage may ensue. (ii) When exploring the liver be prepared to proceed forthwith with aspiration and, as needling occasionally ruptures an abscess, carry out the exploration in an operation room so that immediate open operation may be undertaken if necessary. *Precautions*

Gas and oxygen is the ideal anaesthetic. Most workers in the tropics use local infiltration with Novocain but, despite theoretical disadvantages, intravenous anaesthesia is most useful. *Anaesthetic*

An aspiration needle of medium bore should be used. It should be inserted through the chest wall to a depth of not more than three and a half inches at the point of maximal tenderness, bulge or dullness. A point near the anterior axillary line in the eighth or ninth costal interspace is most commonly employed. The needle should be directed slightly upward and backward. Insertion at several points may be needed before pus is struck. Never attempt to aspirate through the anterior abdominal wall. A sample of pus should be sent for culture if possible. It is not advisable to inject anything into the abscess cavity. Sometimes two or three aspirations at weekly intervals are necessary to get rid of all the pus. *Technique* *Bacteriological examination*

(*c*) *Open operation*

This is indicated when the abscess threatens to point in the epigastrium; if there is a large bulge in the left lobe of the liver; if secondary infection with organisms of sepsis has occurred. *Indications*

(i) *Abdominal section.*—The abdomen should be opened over the most prominent part of the bulge and the intestines well packed off. The abscess *Technique*

should then be *incised and evacuated with the aid of a sucker*. After removal of all necrotic material which can be broken down with the aid of the gloved finger, primary suture may be attempted and the abdomen closed, but in view of the intensely irritating nature of even small amounts of amoebic debris it is

Drainage

generally advisable to drain for a few days through a rubber tube well packed round with sulphonamide gauze.

(ii) *Approach through the ribs.*—An infected abscess in the upper portion of the right lobe may be approached after resection of one or more ribs in the

Two-stage operation

posterior axillary line. The operation may be performed in two stages, with rib resection and suture of the diaphragm to the wound margins forming the first stage. When adhesions have formed incision of the diaphragm with insertion of a tube completes the operation.

(3) Post-operative

Concentrated alcoholic drinks and highly spiced foods should be avoided. Thorough treatment of the primary focus in the intestine is essential. If possible, a long holiday in a temperate climate should be prescribed.

In a high *proportion of cases in temperate persons there is no recurrence.*

8. NON-HEPATIC SECONDARY AMOEBIASIS

(1) Pulmonary

Signs and symptoms

Whilst the majority of cases of lung involvement are due to direct spread through the diaphragm from a manifest primary focus in the liver, it is not *uncommon to meet with cases with no clinical liver trouble,* but with basal pulmonary consolidation, malaise, slight pyrexia, chronic cough and blood-stained purulent sputum. Radiography shows broncho-pneumonic patches at

Emetine

the bases of the lungs. Response to emetine treatment is immediate and *this treatment should always be given a trial* in the tropics in suspected lung abscess before exploration or operation is undertaken. Amoebae are not found in the sputum.

(2) Cerebral

Amoebic brain abscess is occasionally found *post mortem* in cases of long-standing hepatic amoebiasis. It has rarely been diagnosed during life.

(3) Spleen and epididymis

These are occasionally involved and the response to emetine treatment is satisfactory.

(4) Skin

Cutaneous amoebiasis commences at the anal margin or at the edge of a drainage or colostomy wound. *It gives rise to a rapidly spreading ulceration* of the skin. Vegetative amoebae abound in simple scrapings. Emetine treatment is satisfactory.

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AMPUTATIONS

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1. INDICATIONS

(a) Severe trauma

24.] Destruction of bone by itself is never an indication for immediate amputation; the governing factor is the amount of damage to the main vessels and nerves, particularly the vessels.

(b) Danger to life

The patient's life may be in danger from malignant growth, gangrene or sepsis.

Malignant growth

It has been the custom to amputate as high as possible for a malignant growth. Since, however, death is due to metastases and not to local recurrence, it probably suffices to amputate at the next site of election above the tumour. Even when metastases are known to exist it is often an advantage to amputate, when the bone is broken or the skin ulcerated, in order to make the patient comfortable.

Gangrene

When gangrene is the result of or the prelude to sepsis, the limb may have to be sacrificed to prevent death from toxaemia. The dreaded war complication of gas gangrene is caused by anaerobic bacilli. The bacilli cannot thrive and propagate except on dead tissue and this is provided by the lethal action of the crushing and blasting forces of the missile. If this dead tissue can be got rid of at an immediate operation the anaerobic bacilli have little chance of gaining a foothold. The object of a wound-toilet operation is often misunderstood. The intention is not to clear the wound of infecting organisms—that is not possible—but to starve them by removing all dead and dying tissue that might supply them with nourishment. This method of treatment is nowadays also applied to gas gangrene, and amputation, which formerly was the only treatment, is now reserved for cases that are not checked by a thorough scavenging operation.

In gangrene unassociated with sepsis, such as thrombo-angiitic and senile gangrene, amputation may be called for on account of intractable pain.

Sepsis

It is doubtful whether amputation ever saves life in acute sepsis, for the danger then comes from septicaemia, which is not influenced by the removal of the source of the infection. On the other hand, in chronic sepsis, amputation is effective since the danger to life is from toxaemia, and the removal of the source of the infection cuts off the supply of toxins. Amputation is therefore often advisable in chronic infections, such as persistent acute osteomyelitis and tuberculosis of bones and joints in the adult.

(c) Recurrent liability

A leg may be more bother than it is worth. Chronic ulceration of the skin or chronic osteomyelitis may cause the patient to be repeatedly bedridden; perforating ulcers in the sole associated with sciatic nerve palsy may make walking impossible; severe and constant pain in progressive arterial degeneration may render life intolerable.

(d) Cosmetic reasons

When a leg is three inches or more short, amputation is often advisable provided that the hip and knee joints are normal, because an unnoticeable artificial limb is much to be preferred to the ugly appearance of a high boot. Nothing is sacrificed in the way of function, for the shortening renders impossible a normal toe-and-heel gait.

(e) Useless limb

This indication is mentioned with the caution that it rarely applies. A lower limb even though severely paralysed can be used as a peg; and infantile paralysis and sciatic palsies, *qua* paralysis, are never an indication for amputation, although the accompanying trophic ulcers may be. In the upper limb, the indication applies even more rarely except in the case of an irrecoverable complete brachial plexus lesion. The retention of the slightest movement between a finger and a thumb makes the hand of greater value than any artificial limb.

Artificial limbs

The substitution value of an artificial limb varies greatly in the two limbs. A patient may walk almost naturally with an artificial leg, but no artificial arm can replace the ordinary prehensile action of the fingers. Amputation of the upper limb is never to be lightly decided upon, and its necessity should be confirmed by a second opinion. Moreover, the site of amputation has a bearing on its advisability. The above-knee amputee is more disabled than the below-knee amputee, and the above-elbow amputee much more than the below-elbow amputee. Many patients with an amputation above the elbow will not bother to wear an artificial arm.

2. KINDS OF AMPUTATION

The surgeon who aims at making the stump fit the prosthesis rather than the prosthesis fit the stump is subordinating himself to the limb-maker; but he is powerless to do otherwise, for it is futile to present to the limb-maker a stump for which he has no suitable model. The surgeon is right to refuse to sacrifice any joint over which the patient has voluntary control, but apart from this he should be prepared to give the limb-maker the length and shape of stump he asks for.

Unless a surgeon can guarantee a stump that will satisfy the requirements of the limb-maker, he should plan to do two amputations: a preliminary or *provisional* amputation, followed at a later date, when the requirements can be met, by a final or *definitive* amputation at a higher level. Provisional and definitive amputations differ in their indications, their sites and their techniques.

3. PROVISIONAL AMPUTATION

If healing by first intention is at all doubtful, a provisional amputation should be preferred to a definitive amputation.

Since it is not intended to fit a prosthesis to the stump, a provisional amputation is no concern of the limb-maker, and the surgeon need be governed only by surgical considerations in his choice of site and technique.

(1) Site

In all probability the wound will not heal without infection, and it is wise therefore to amputate as low as possible in order to preserve unsoiled the tissues that will be cut through at the definitive amputation. The amputation should of course be done through viable tissues, but there is no need to go above the level of the infection. Infection, even of bone, quickly disappears given adequate drainage, and an amputation affords excellent drainage, inasmuch as all the tissue planes are cut transversely. By amputating through

instead of above the infected area, the neighbouring joint can often be retained at the definitive amputation, as, for example, in the case of a grossly infected ununited fracture of the tibia, when a provisional amputation at the site of the fracture often heals in a few weeks.

Healing without infection

It sometimes happens that a provisional amputation heals without infection and the resultant stump, although not ideal as regards mobility of skin, is fittable. This unexpected outcome is likely to be increasingly seen in the future with the introduction of sulphonamides and penicillin. But, though fittable, the stump may be too long to take the best type of prosthesis because there is not room enough below the socket for the joint mechanism. Accordingly the old injunction to "amputate as low as possible" is nowadays being modified to "amputate as low as possible but never less than three inches above a joint".

(2) Technique

The technique for a provisional amputation, including the fashioning of the skin flaps, is the same as that for a definitive amputation, with the exception that the deep fascia and the skin are not sutured.

The old-fashioned guillotine operation, at which skin, muscles and bone were all cut through at the same level, provides better drainage, but it has the drawback of leaving a large raw area which is painful to dress and takes a long time to granulate. Drainage when skin flaps are cut but not sutured is adequate, and the rapidity of healing and the greater comfort are well worth the sacrifice of the superfluous degree of drainage. Healing is much quicker if the skin edges are sewn together for an inch in the centre so as to cover the raw end of the bone, otherwise this area takes a very long time to heal. When the infection is of long standing it is safe to do this partial closure, but when the infection is recent and severe, drainage is more imperative and even partial closure is unsafe. In an early amputation on a battle casualty no stitches at all should be inserted. A few days later, when the patient reaches the base hospital and infection is under control, delayed primary suture may be undertaken.

4. DEFINITIVE AMPUTATION

(1) Time

Terminal ulcer

It is often difficult to know when it is safe to perform the definitive amputation. Ideally, a definitive amputation should not be done unless primary healing is certain, and this cannot be guaranteed while the provisional amputation remains unhealed. There may, however, be a terminal ulcer that refuses to heal, and a certain amount of risk has then to be accepted. The risk of infection can be minimized by waiting until the disappearance of surrounding oedema and tenderness and the appearance of a healing edge all round the ulcer. Clinical observation of the ulcer and its surroundings is more trustworthy than information gained from culturing the surface. In any doubtful case penicillin should be administered just before and for a few days after the re-amputation.

(2) Methods of transmitting stress from prosthesis to stump

Stress can be transmitted in three ways: through the bottom of the stump—*end-bearing*, through the sides of the stump—*lateral-bearing*, and, in the

lower limb, direct to the pelvis—*ischial-bearing*. The site chosen for an amputation depends upon the method of transmitting the stress.

There is no problem in the upper limb where the usual stresses are lateral. In the lower limb, where the main function is weight-bearing, the transmission of an upward thrust is the important factor. This can be effected by end-bearing, lateral-bearing or ischial-bearing. End-bearing, by which the weight is taken directly on the end of the bone, would seem at first sight the obvious method. However, for a long bone to transmit weight, its bearing surface must be large and composed of solid bone. These two requirements can be met only if the bone is sectioned close to an articular surface. If the bone is divided elsewhere, the end forms a ring of bone with nothing in its middle and the bearing surface is so narrow that it acts as a knife edge. Unfortunately, the best type of prosthesis cannot be fitted to a stump of extreme length because there is no room for a complicated joint-mechanism inside the socket. Moreover, to bear weight satisfactorily on the end, the stump must have healed *per primam*. British surgeons therefore generally follow the advice of the limb-fitting surgeons at Roehampton and aim at producing lateral-bearing or ischial-bearing stumps.

(3) Sites of election

Length of stump

When a stump is not intended to bear weight on the end, its length is governed by two factors, namely, the longer the stump the better its leverage, and the shorter the stump the better its circulation. The sites of election are a compromise between these two claims. Whatever length is chosen the stump (a) must be three inches shorter than the entire bone in order to give room inside the socket for the joint mechanism, (b) must be long enough to contain the insertion of the muscles controlling the stump and (c) must be long enough to remain inside the socket during flexion of the joint.



Fig. 66.—Bilateral below-knee amputation showing ideal length and shape.

Experience shows that there are two sites of election in the lower limb and two in the upper limb. These are respectively below the knee and above the knee; below the elbow and above the elbow.

(a) Below knee

A below-knee stump should measure five and a half inches from the level of the knee joint to the end of the tibia (*see* Fig. 66).

Actually four inches is enough, for a four-inch stump contains the insertion of the knee flexors and knee extensors and is long enough to remain inside the socket during flexion of the knee. It is better, however, to aim at a length of five and a half inches because the below-knee amputation is apt to give trouble in healing. Not infrequently the skin edges pull apart or slough,

leaving a chronic ulcer at the end of the stump. Should this happen, one can, by sacrificing an inch of spare tibia, excise the ulcer and suture the skin edges without tension.

The shortest stump that can be fitted with a below-knee prosthesis depends upon the bulkiness of the subcutaneous tissues, and the prominence formed by the hamstring tendons. About two inches is the limit.

(*b*) *Above knee*

The above-knee stump should measure eleven inches from the top of the trochanter to the end of the femur (*see* Fig. 67).

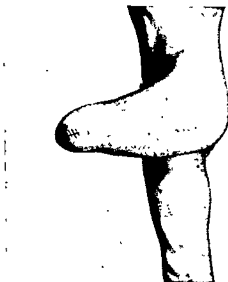


FIG. 67.—Above-knee amputation showing ideal length and shape.

Inasmuch as the adductor muscles are inserted all the way down the shaft of the femur, the stump must be at least nine inches long to retain sufficient adductor power. The loss of every inch of femur renders muscular control of the hip more difficult, and as much as possible up to eleven inches of femur should be left. In a tall man without arterial disease more may be granted, but the end of the stump must be three inches above the level of the knee to leave room for the fitting of the mechanism of the artificial knee joint.

Disarticulation at the hip

When the stump is too short to remain inside the socket during movement at the hip, the amputee has to wear a tilting-table limb. The minimal length that will take an above-knee prosthesis depends upon the bulkiness of the subcutaneous tissues. But even when a tilting-table is inevitable, the limb-makers like four inches of femur left, measured from the top of the trochanter. This small fragment flexed to a right angle affords two prominences, one in front formed by the end of the stump, and the other on the lateral aspect formed by the great trochanter, round which the socket can be moulded. The tendency for the socket to rotate on the pelvis is thereby diminished. Limb-makers dislike having to fit a disarticulation at the hip joint. In a woman a high thigh amputation should be done at the level of the small trochanter because she objects to any lump showing through her clothes.

(*c*) *Below elbow*

In the upper limb the transmission of weight is not a main consideration, and the stump is subjected more to lateral than to longitudinal stresses. Nor does a long stump in the upper extremity suffer, except to a minor degree, from defective circulation. It would seem, therefore, not to matter much where the amputation is done, provided that room is left for the mechanism of the artificial joint, for which three inches should be allowed. The limb-fitting surgeons declare that the optimal length from a below-elbow amputation is seven inches, measured from the tip of the olecranon to the

end of the bone (*see* Figs. 68 and 69).

Minimal length

As regards minimal length, there must be at least one inch of ulna below the prominence formed by the biceps tendon when the elbow is flexed to a right angle.



FIG. 68.—Below-elbow amputation showing ideal length and shape.

Many surgeons amputate through the wrist joint with the idea of retaining active rotation of the forearm. This amputation is disliked by the limb-maker since it gives him no room to fit the wrist-joint mechanism. As a matter of fact, rotation of the forearm is incompatible with the wearing of the present-day prosthesis, because the socket has to fit snugly to be retained, and this close fit does not permit the alterations in shape that the forearm necessarily undergoes during rotation. It is to be hoped that in future a socket will be devised that will allow the wearer to rotate his forearm, for loss of rotation is a severe handicap. Fingers, or even parts of fingers, should, of course, never be sacrificed, but in the absence of a remnant of a finger or thumb re-amputation through the forearm is probably advisable, with the prostheses as yet available.

(*d*) *Above elbow*

The above-elbow stump should measure eight inches from the acromion process to the end of the humerus.

Minimal length

As regards minimal length, there must be at least one inch of humerus below the prominence formed by the anterior fold of the axilla; a stump shorter than this does not remain inside the socket during movement of the shoulder.



FIG. 69.—Below-elbow amputation showing ideal length and shape.

As in the lower limb, and for a similar reason, the limb-maker does not like a disarticulation at the shoulder. The retention of an inch or so of the humerus facilitates anchoring the socket to the chest wall.

(4) Technique of amputation at sites of election

In the ideal stump, the scar is not exposed to pressure, nor is it adherent, the skin is not infolded, there is no redundant soft tissue, there is no protruding

spur of bone, the stump is not tender and the wound has healed by first intention.

(*a*) *Position of scar*

In the days when end-bearing was the aim, great care was taken to keep the scar away from the end of the stump. This was effected by cutting unequal flaps, usually a long anterior and a short posterior, which located the scar on the posterior aspect about an inch from the end of the stump. However, now that end-bearing has been given up, there is no longer the obligation to avoid a terminal scar, and though there is still a liking for a posterior scar in the lower extremity, equal flaps are advocated for all four amputations. There is much to be said for choosing a simple technique applicable to all four amputations, because any surgeon whatever his speciality—and even at times the physician—may be called upon to amputate. Besides, amputations in peacetime are not common and few surgeons have the opportunity of becoming proficient in this branch of surgery.

Direction of scar

Regarding the direction of the scar, an antero-posterior scar is a disadvantage in the forearm and the leg, because it is apt to be pulled up between the two bones and form a sulcus. There is no objection to a transverse scar in any amputation. Therefore, since a posterior scar has no advantage over a terminal, and an antero-posterior scar no advantage over a transverse, it is wise to choose equal antero-posterior flaps for all four amputations. This will ensure a transverse terminal scar.

In cutting the skin flaps one must remember that the modern socket is conical in shape and demands a conical stump. The skin flaps therefore should be semicircular and not oblong.

(*b*) *Non-adherent scar*

Piston-action

A physiological fact—perhaps not widely realized—is that the skin normally moves freely over the underlying tissues. This mobility depends upon the deep fascia. Now, when an amputee walks, the prosthesis slides up and down the leg at each successive step; as he puts his foot to the ground the stump descends inside the socket, and as he takes his foot off the ground the stump pulls up out of the socket. This up-and-down motion, known as *piston-action*, takes place not between the socket and the skin but between the skin and the underlying soft tissues. If the skin moves freely, piston-action does not exert tension on the deep tissues; if the skin is adherent, piston-action is communicated to the deep tissues, and the continual drag irritates the nerve-bulbs and the stump becomes painful. The structure that normally allows the skin to move freely over the deep tissues is the deep fascia, and where the deep fascia is wanting the skin becomes adherent. The deep fascia thus assumes great importance in an amputation, and it should be sutured as carefully and as accurately as the skin. With this end in view, after the skin has been divided the deep fascia is cut through at the same level, and the skin and deep fascia reflected back as a single layer. On completion of the amputation the deep fascia is identified, in much the same way as is the peritoneum in closure of the abdomen, and accurately sutured. A scar adherent to the end of the bone is not so detrimental as a scar adherent to the soft tissues. Many a guillotine amputation with its large papery terminal scar has been fitted satisfactorily without re-amputation. Piston-action on such a stump puts tension on the

inert bone, whereas piston-action when the skin is adherent to the soft tissues puts tension on the sensitive nerve-bulbs.

(c) Infolding of skin

The only difficult part of an amputation is the planning and fashioning of the skin flaps. Folds of skin at the end of a stump are a nuisance, for intertrigo is apt to develop in the sulci and spread as a septic eczema over the end of the stump. Infolding of the skin is inevitable unless the perimeters of the two skin flaps are of equal length, and it is difficult to cut unequal flaps in such a way that they have equal perimeters. This is a further argument for choosing equal flaps in all amputations. Even so, one is often disappointed to find that, although one has striven to cut equal flaps, the anterior flap has a smaller perimeter than the posterior flap, and this tendency should be borne in mind when planning the flaps.

Equal flaps

The longitudinal length of the flaps should be such that the skin edges come together without tension, that is, each flap should measure half the antero-posterior diameter of the limb.

(d) Redundant soft tissues

A bulky mass projecting beyond the end of the bone serves no useful purpose and, being uncontrolled, is difficult to insert into a conical socket. The limb-makers ask that muscles should be cut at the same level as the bone and not sewn over the end of the bone.

(e) Protruding spur of bone

In amputations of the upper extremity and in the above-knee amputation, it is correct to cut through the bones transversely. In the below-knee amputation, the sharp anterior angle of the tibia should be bevelled, and the fibula should be cut one inch shorter than the tibia. Unless the fibula is shortened it may project beyond the tibia and the skin over it may ulcerate. Another reason for shortening the fibula is the prevention of cross union. If the fibula remains independent it acts as a spring which, on being compressed by the socket, renders more exact the apposition between the socket and the stump. Total removal of the fibula is deprecated.

(f) Tender stump

Neuromas form on the proximal ends of all divided nerves, but except in a stump they are hardly ever painful. There are three obvious causes for painful neuromas: (i) pressure from the socket, (ii) traction from piston-action and (iii) traction from muscle pull.

Pressure of the socket

The only part of the stump that is certain to be immune from pressure is the end, for this does not come into contact with the socket. It is desirable, therefore, to leave the nerves as long as possible. They are best cut through with the muscles and afterwards left undisturbed.

Traction from piston-action

Piston-action will not be communicated to the neuroma if the skin moves freely over the deep tissues. This can be attained by sewing together the two layers of deep fascia just before closing the skin.

Traction from muscle pull

The less the nerves are interfered with at the time of operation, the less likely are they to become adherent to the neighbouring tissues. Some adhesions are probably inevitable, and it is advisable to get the patient to contract his muscles and to move his stump about as soon as possible after the operation, so that adhesions are stretched before they become inelastic.

(g) *Primary healing*

While it is true that many stumps that did not heal by first intention have been satisfactorily fitted with artificial limbs, it is equally true that primary healing is the best guarantee that the stump will never give any subsequent trouble. Nothing, therefore, should be left undone to ensure the absence of sepsis. Sepsis is nearly always preceded by a haematoma, and the problem of avoiding sepsis is the problem of avoiding a haematoma. The most meticulous attention should be paid to haemostasis and every tiny bleeding point should be tied or cauterized. The value of drainage is debatable. A drain rarely lets blood *out* and it may let infection *in*. On the other hand, the removal of a drain at the end of forty-eight hours leaves a channel for the release of a pent-up haematoma. The patient ought to be reasonably comfortable on the day after the amputation. Should he have pain it is wiser to dress the wound, and if the stump is distended with blood the surgeon had better pocket his pride, reopen the wound and secure the bleeding point.

Whether to drain

(5) Below-knee amputation (*see* Fig. 70)

Technique

A tourniquet is a matter of choice in most amputations, but it is best not used in cases of arterial disease.

A wooden wedge is placed under the leg just below the knee.

Five and a half inches from the knee, two points A and B are marked on the skin, one on either side of the leg, so that the line AB across the front of the leg equals in length the line BA across the back of the leg. A surgeon accustomed to amputating at this level can gauge by eye the correct positions of A and B. A more accurate method is to fix the point A, measure the circumference at this level, and then place B so that AB equals half the circumference.

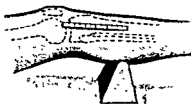
Equal antero-posterior semicircular flaps are cut, each equivalent in length to half the antero-posterior diameter of the leg. The skin incisions are deepened to include the deep fascia. Over the front of the tibia, where the deep fascia is absent, a layer of periosteum is reflected off the tibia to form a single sheath with the deep fascia on either side of the bone. The flaps, consisting only of skin and fascia, are dissected back to just above the level AB.

With the flaps retracted, the front of the tibia is bevelled at the highest point by sawing obliquely half way through it. Then, the tibia and fibula are sawn through transversely at the level of AB. As soon as the fibula has been divided, the remaining soft parts are cut through at the level of the bone section and the amputated portion of the leg discarded.

The leg being held at an angle of forty-five degrees, the main vessels are clamped, the tourniquet is released and other bleeding points secured. It is a good plan to clamp the main vessels again at a slightly higher level so that two separate ligatures can be applied. After the main vessels have been ligated the remainder are either tied or cauterized. The nutrient artery in the posterior wall of the tibia, if troublesome, can usually be obliterated by pressure from a bone-nibbling forceps.

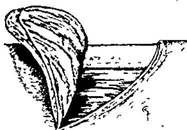
One inch of the fibula is now removed by bone forceps, after the bone has been exposed subperiosteally by a rugine.

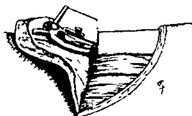
After a further search for bleeding points the wound is ready for closure. The anterior layer of the deep fascia is carefully sewn to the posterior layer; then a clean towel is placed under the limb and the skin is sewn. If the towel

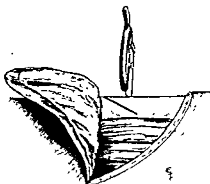

(a) Six-inch ruler defining level of bone section.


(b) Thumb and finger defining base of flaps.


(c) Skin incision deepened to divide deep fascia.


(d) Skin and fascia reflected back as a single layer.


(e) Preliminary oblique saw-cut through half of the tibia.


(f) Tibia about to be sawn through.

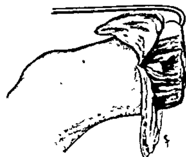
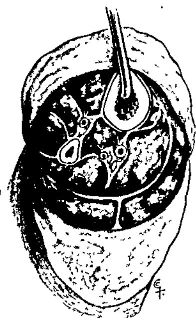
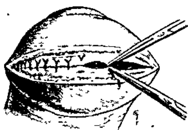

(g) Muscles and bone cut through at the same level. Note long retractor hooked into medulla of tibia.

FIG. 70.—Below-knee amputation. Technique.



(h) Face of amputation showing the three main vessel bundles.



(i) Suturing of deep fascia.



(j) Suturing of skin.



(k) Final appearance.

FIG. 70.—Below-knee amputation. Technique. (*cont.*)

is not soiled by more than few drops of blood, haemostasis can be reckoned satisfactory; in any case of doubt it is better to remove the sutures from the deep fascia, open the wound and secure the bleeding points.

The incision is covered with tulle gras to make the first dressing comfortable.

A firm bandage is applied, and the knee is bound down to a straight back splint, which may be removed next day.

(6) Above-knee amputation

Technique

A deep wooden wedge is placed under the middle of the thigh.

Eleven inches from the top of the trochanter a point A is marked on the middle of the outer side of the thigh. At the same level another point B is marked on the inner side of the thigh, such that AB measures half the circumference.

Antero-posterior flaps, semicircular in shape and each equal in depth to half the antero-posterior diameter, are cut, and the incisions deepened to divide the deep fascia. The two flaps, containing only skin and deep fascia, are reflected to the level AB and retracted. The muscles are cut through at the level AB and retracted, the bone is sawn through transversely at the same level and the amputated portion of the leg discarded. There is no need to reflect periosteum.

The main vessels are then clamped and the tourniquet released, if one has been used. Often it is sufficient to get the anaesthetist to compress the femoral artery against the pelvis while the muscles and bone are being sectioned.

All the remaining bleeding points are now secured, the procedure being rendered less tedious if the stump is held vertical. Besides various muscular branches there is an artery in the sciatic nerve bundle and also a perforating vessel close to the under surface of the femur. The vessels are tied. It is a wise precaution to apply two separate ligatures on the main vessels.

After all bleeding has been checked the wound is ready for closure. The stump is allowed to sink almost to the horizontal, supported only by the wedge underneath it. The anterior layer of deep fascia is joined to the posterior layer by interrupted catgut sutures. A clean towel is then placed under the limb and the skin is sewn. If this towel is stained by only a few drops of blood, haemostasis may be considered satisfactory. When there is doubt, it is better to reopen the wound and pick up the bleeding points that have been missed.

The incision is covered with tulle gras to render the first dressing comfortable, and a roll of gauze is wound tightly over the end of the stump. To keep the dressing in place a strip of Elastoplast is stuck to the front of the thigh, passed down over the end of the stump and stuck again to the back of the thigh.

5. AFTER-TREATMENT

The surgeon's work does not finish with the operation; he still has to prepare the stump for the fitting of a limb and to teach the patient how to use the limb.

(1) Preparation of stump

This embraces shaping the stump, strengthening the muscles, regaining movement at the joint above and reconnecting the brain to the stump.

Shaping the stump.—The stump has to be converted from a wide cylinder to a narrow cone. Time will effect the change, but the process can be hastened by compression of the stump. This is done (a) by bandaging or (b), in the lower extremity, by wearing a temporary prosthesis (commonly called a pylon) (*see* Fig. 71, in which the patient also has a forearm amputation with a plaster gutter incorporated in the crutch).

Temporary prosthesis

The pylon for a thigh amputation is made up of a plaster or fibre socket moulded to take weight under the ischial tuberosity. The socket is fixed to


(a)


(b)


(c)


(d)

FIG. 71.—Method of getting double amputee to the erect position: (a) Patient grasps overhead rings. (b) Chair is removed as he pulls himself vertical. (c) View of overhead rings suspended from parallel bars. (d) Patient, having got his balance with the help of the rings, standing with crutches.

A firm bandage is applied, and the knee is bound down to a straight back splint, which may be removed next day.

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(2) Prosthesis—teaching its use

To walk without a limp with an above-knee prosthesis, the amputee has to be taught. The teaching consists essentially in *making him balance* on his artificial limb. Balance is normally maintained by the foot muscles, whereas an amputee has to learn to balance by using the muscles of his hip. An artificial arm is even more difficult to use without instruction, and an armless man is tempted to discard his prosthesis as more bother than it is worth unless he is trained to use it.

6. TROUBLESOME STUMPS

(1) Eczema

This is common. Frequent changing of the stump sock and the application of an antiseptic ointment, such as Unguentum Hydrargyri Nitratis Dilutum, sometimes suffices to get rid of the infection. Ultra-violet rays act like a charm. Often it is necessary to cease wearing the artificial limb for a while.

(2) Septic dermatitis

The sweat glands on the inner side of the thigh at the level of the top of the socket may become infected and tender lumps form in the skin which, on being squeezed, exude pinpoints of pus. This condition, which is referred to as an "adenoma of the groin", is induced by a badly fitting socket which compresses the adductor region. The inflammation at times becomes so acute that the limb cannot be worn. After a period of rest and an alteration in the shape of the socket the amputee is usually able to resume wearing his limb. If he is still uncomfortable the whole of the inflamed skin down to the deep fascia should be excised.

(3) Skin callosities and bursae

These are common in a below-knee stump over the head of the fibula and the inner tibial tuberosity. They are a limb-fitting problem and are cured by changing over from tibial-bearing to ischial-bearing. Should a bursa become infected, incision is called for, but there is no need to excise the bursa.

(4) Ulceration

An ulcer on the end of a stump is caused by defective circulation, an ulcer elsewhere usually by friction. When the defect in circulation is local the ulcer should be excised and healthy skin edges sutured *without tension.* It may be necessary to sacrifice an inch of bone to be sure that there is no tension on the suture line. When the defect in circulation is general and due to diminished blood supply to the limb or to varicose veins, re-amputation at the next site of election is required. It is not always easy to decide whether the cause is local or general; the vascularity of the skin surrounding the ulcer guides one in making a decision.

An ulcer elsewhere than on the end of the stump is caused by the friction of the socket on skin that is immobile. It is usually impossible to regain mobility of the skin and the socket must therefore be ballooned to avoid touching the ulcer. The ulcer should be allowed to heal before limb-wearing is resumed.

(5) Sinus

A sinus indicates a grumbling inflammation or the presence of some dead or foreign material. Skiagrams bring to light a sequestrum or a metallic foreign

lateral wooden supports (the lower end of a crutch serves the purpose) and a knee joint is not incorporated. For a leg amputation the socket is made of plaster moulded round the upper end of the tibia. This is fixed to wooden lateral supports and is jointed to a corset made of fibre, which is laced round the lower half of the thigh.

A pylon enables the patient to dispense with crutches early, and with its aid the patient can learn to balance so that he uses his permanent prosthesis correctly as soon as it is fitted.

Strengthening the muscles.—This applies especially to the above-knee amputation. The particular muscles in need of strengthening are the adductors and the extensors; the adductors because part of their insertion has been



FIG. 72.—A patient with a thigh amputation exercising the hip extensors.

lost, and the extensors because they have in future the double task of extending the hip and extending the artificial knee. The muscles are strengthened by exercises against a weight and pulley.

Regaining movement at the joint above.—Much can be done by prophylaxis. A stump should not be nursed on a pillow, and the patient should be encouraged to move the joint as soon as possible after the operation (*see* Fig. 72). Flexion deformity at the knee and flexion abduction deformity at the hip are especially to be avoided. Should a deformity develop, movement can usually be restored by the weight and pulley exercises used for strengthening the muscles.

Reconnecting the brain to the stump.—This is vital. The damaged limb has often been lying inert for many months, and communication between the brain and the muscles is suspended. Unless it is restored the patient will not be able to control the prosthesis by the muscles of his stump. The damaged extremity can readily be restored to consciousness by being given something to do. The simplest method is to make the patient play with a large soft india-rubber ball, which he can propel with his stump whatever the level of the amputation.

The wearing of an artificial limb may renew a cellulitis or an osteomyelitis. If the skiagram shows a bone cavity or a sequestrum, operation is indicated, but otherwise the inflammation should be treated by rest. *Re-activated infection*

Spurs at the end of the bone are frequently seen in skiagrams. These do not cause symptoms and do not require removal. They are due to exuberant subperiosteal osteoblasts which spread a short way into the neighbouring muscles; the process is not inflammatory. However, a low-grade inflammation may smoulder about the end of the stump and give rise to irregular new bone formation. This differs from a spur in having an irregular outline and in extending all the way round the shaft. The bone remains sensitive to touch and often re-amputation an inch or so higher is advisable. Sometimes the skiagram shows a ring sequestrum within the new bone. If so, the sequestrum should be removed before re-amputation is undertaken. Not infrequently the stump becomes comfortable after the removal of a sequestrum and, in spite of the massive new bone, tolerates a prosthesis. *New bone formation*

(7) Joint deformity

The two types commonly met with are flexion deformity at the knee and flexion-abduction deformity at the hip. The artificial knee of a prosthesis is set in slight hyperextension, so that the wearing of a prosthesis gradually corrects a flexion deformity due to contracture of the soft parts. Treatment from the surgeon is rarely called for, except where the deformity is gross, when it can be corrected by gradual splintage. *At the knee*

Flexion-abduction at the hip is not diminished by limb-wearing, and is difficult to correct by splintage. Usually the limb-maker allows for the deformity in shaping the socket, but since the amputee can never attain a graceful walk, it is better to correct the deformity by a subtrochanteric osteotomy. *At the hip*

7. END-BEARING AMPUTATIONS

Although in Great Britain end-bearing has gone out of fashion, the Americans and Canadians still advocate the Stokes-Gritti and the Syme amputations. To take weight on its end a stump must have certain attributes. The cut surface should, of course, be horizontal, but more particularly (1) the whole of the bearing surface must consist of compact bone, (2) the deep tissues must adhere firmly to the bone and (3) the skin over the end of the stump must be well nourished and mobile.

(1) Bearing surface of compact bone

After World War I there was a tendency to modify the technique of the Stokes-Gritti and the Syme amputations by cutting the bone one inch from the end to make room for the joint of the prosthesis. The section passed above the limit of the cancellous bone, and the bearing surface consisted ultimately of a ring of compact bone with nothing in the centre. The skin could not tolerate pressure on this narrow bearing surface. To distribute the pressure widely, a large platform of bone is needed, and this can be obtained only by dividing the shaft where it is cancellous, that is to say, near the articular surface and, in fact, the nearer the articular surface the better.

body but do not reveal a non-opaque unabsorbable suture, so that one is often in doubt about the cause of the sinus. With a negative skiagram one should be in no hurry to operate. *Most sinuses heal of their own accord.* A sinus of three months' duration justifies interference, and operation is also advisable when a sinus appears in a stump previously healed.

(6) Pain

It is not always easy to discover the cause of pain in an amputation stump. The answer to the following questions helps the investigation. *Is the pain constant, or elicited only by pressure, by movement, or by limb wearing? Where is the pain felt?* Pain may be due to tender neuromas, ascending neuritis, causalgia, ill-fitting socket or recurrent sepsis.

Tender neuromas

Only when the tenderness is localized should a nerve-bulb be suspected as the cause of the pain. When the tenderness is diffuse the enlarged nerve-bulb, being the only distinctive thing palpable, is apt to be unfairly blamed. Nerve-bulbs are ordinarily insensitive, and sensitivity when present can be explained in several ways. The most obvious explanation is sepsis at the time of the amputation, but it is difficult to believe that this is a prime factor because tender neuromas are not common in healed guillotine amputations. A more likely explanation is that the nerve-bulb is irritated by pressure or traction, especially the latter. When, together with localized tenderness, pain is caused by sliding the skin up and down, or by voluntary contraction of the muscles when the stump is motionless or by passive movement of the stump, a tender neuroma may be accepted as the diagnosis.

A stump with tender neuromas rendering limb-wearing unbearable should be operated upon. It is better to leave the neuromas undisturbed and to divide the main nerves at a higher level, where the subsequently formed nerve-bulbs will not be subjected to pressure by the socket and will not be pulled upon by the skin as it slides up and down. In the below-knee stump the two popliteal nerves are divided behind the knee; in the above-knee stump the sciatic nerve can be approached through an incision above the upper limit of the socket; in the below-elbow stump all three main nerves are divided at the level of the elbow through incisions that will not be touched by the prosthesis; and in the above-elbow stump all the main nerves can be reached in the axilla.

Ascending neuritis

Sometimes inflammatory tissue penetrates the nerve bundles and ascends the nerve sheaths for a considerable distance. On clinical examination the main nerves throughout the stump as well as the terminal bulbs are tender to touch. Division of the nerves, even at the highest possible level, does no good. Although with time the sensitiveness may disappear, these amputees are rarely able to tolerate a prosthesis. Re-amputation at the next site of election is inadvisable, for the new stump is just as painful as the old.

Causalgia

Some stumps are not only diffusely tender but are painful at rest, and the pain is increased by the slightest contact or the slightest movement. Local operations and re-amputations should be avoided. Ramisectomy may be tried. Physiotherapy is not tolerated.

Ill-fitting socket

If a stump is uncomfortable whenever a prosthesis is being worn but becomes comfortable, and ceases to be tender within a few days of leaving off the limb-wearing, the fault is probably in the fit of the socket and the remedy lies with the limb-fitter.

The wearing of an artificial limb may renew a cellulitis or an osteomyelitis. If the skiagram shows a bone cavity or a sequestrum, operation is indicated, but otherwise the inflammation should be treated by rest.

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(2) Deep tissues firmly adherent to bone

Unless the deep tissues constituting the pad over the end of the stump are anchored to the bone, stress cannot be transmitted from the socket to the bone with any certainty; a wobbly pad is inconsistent with stability. Many end-bearing stumps fail on this account.

(3) Well-nourished and mobile skin

The skin over an end-bearing stump is subjected to considerable pressure which it cannot sustain unless it has a good blood supply. Furthermore, the skin at the end has to withstand horizontal as well as vertical stresses, for the socket tends to slide on the skin. Nature has protected skin from friction-stresses by a mechanism that allows it to slide freely on the deep fascia; and in an end-bearing stump, in order that this protective gliding mechanism may be preserved, the skin over the end of the bone must be mobile. It follows that amputations designed with a view to end-bearing should not be performed (a) when the circulation either on the arterial or venous side is not perfect and (b) unless primary healing can be guaranteed. Amputations for senile gangrene, thrombo-angiitis and varicose ulceration, and for sepsis, would come under this ban.

(4) Syme's amputation

(a) General

Opinions differ on the merits of Syme's amputation (*see* Fig. 73). The limb-fitting surgeons at Roehampton, judging from the number of limbs that have had to be re-amputated for various reasons, condemn it. The Toronto school and the Edinburgh school believe the Syme to be an excellent amputation. The Roehampton surgeons argue that the below-knee amputee is no worse off than the Syme's amputee, and can do everything with an artificial limb that the Syme's can do. They say that besides having no advantages Syme's has two disadvantages: the prosthesis never looks anything but artificial since the mechanical ankle is larger than the normal ankle on the other side, and unless the Syme's amputation is expertly performed and heals by first intention, the amputee cannot be comfortably fitted, whereas a comfortable limb can usually be fitted to a below-knee amputee even when the operation was not well performed, and even though the wound did not heal cleanly.



Fig. 73.—Double Syme's amputation.

The Toronto school agree that for aesthetic reasons the Syme's is unacceptable to a woman, but they strongly advocate it for a man in preference to a below-knee amputation.

The argument that a Syme's amputee can get across a room without a limb carries little weight, because all amputees—old and young and whatever the level of the amputation—acquire the knack of hopping across a room on their sound leg. There is, however, no denying that from a patient's point of view an amputation just above the ankle appears less of a catastrophe than an amputation through the upper part of the calf. The appeal to the surgeon is always the same: "Don't take away too much".

The occasions must be few when it is possible to do a clean Syme's amputation, and yet not have sufficient skin to retain the os calcis. It is likely that many amputees with successful Syme's amputations could have been left with part of a foot. Partial amputation of the foot gives excellent results, for even in those patients in whom an equino-varus deformity has developed, the foot can be made plantar-grade and stabilized by tendon transplants and arthrodeses. Syme's amputation should be reserved for the expert, but an even greater expert might succeed in saving part of the foot.

(*b*) *Technique*

For a Syme's to be successful (i) the wound must heal *per primam*, (ii) the internal and external plantar arteries in the flap must not be damaged, (iii) the tibia must be sectioned as low as possible and (iv) the heel pad must be made to adhere firmly to the bone.

The foot is dorsiflexed to a right angle before the skin flaps are cut, and the leg rests on a sand-bag to elevate the foot from the table. Two points A and B are marked on the skin: A, a finger's breadth below and in front of the internal malleolus, and B, the tip of the external malleolus. Two skin incisions are made, the anterior joining A to B across the front, and the posterior passing vertically down from A across the under surface of the heel and vertically up to B. Both incisions are carried down to bone. The foot is plantar-flexed and the ankle joint lies open. The surgeon then removes the foot by cutting the soft structures off the astragalus (talus) and the os calcis, *keeping all the time close to the bone* and cutting always towards the bone. After removal of the tourniquet the two plantar arteries are ligated at their extremities. The main artery, which can be palpated, serves as a guide to the internal plantar nerve, and this is cut as high as possible but is not pulled down. The dorsal flap is then dissected up to expose the internal malleolus and the tibia is sawn through as low as possible; unless a small portion of articular cartilage remains on the shaft the section has been made too high. Great pains are taken to cut the bone horizontally. If the raw surface is not quite horizontal, the surface is filed until it is. The tendons are pulled down one by one and cut short, care being taken of the vessels. The flaps are then approximated by two tension sutures to test the position of the scar, which should be a quarter of an inch above the end of the bone. Deep sutures are inserted from the heel flap to the periosteum on the front of the tibia. The wound is drained. "Dog-ears" are best left; they disappear subsequently and trimming the flaps is undesirable for fear of damaging the vessels. After the skin is sutured the flaps are held in position by two loops of Elastoplast, one antero-posterior and the other lateral. Two days later the drain is removed and the strapping readjusted, if necessary, to centralize the flaps. Strapping is continued for three weeks until the heel flap has firmly adhered to the bone. Weight-bearing on a pylon is permitted at the end of the sixth week.

(5) Stokes-Gritti amputation

Success depends upon getting the patella to fuse with the femur. With the thumb and forefinger on the condyles of the femur at the level of the adductor tubercle, two flaps are cut: a long anterior and a short posterior (about one inch). The anterior should be broad, about three-quarters of the circumference, and extend to midway between the lower pole of the patella and the tubercle of the tibia. The anterior incision is carried down to bone and the flap containing the patella and quadriceps expansion is reflected upwards. The femur is then sawn through horizontally at the level of the adductor tubercle. The vessels are clipped and the soft parts divided. The under-surface of the patella is rawed by a saw-cut parallel to its surface. Two holes are drilled from before backwards in the femur, half an inch from its end, and two holes are drilled through the patella to correspond. A thick suture is threaded through each hole in the patella and the corresponding hole in the femur. The thigh is now raised vertically to relieve the strain on the quadriceps, and while the patella is pressed firmly against the raw surface of the femur the sutures are tied. It is immaterial that the femoral surface is larger than the patella. The patellar tendon is sewn to the cut hamstrings. The wound is drained. As in a Syme's amputation the wound is firmly strapped until the patella has fused solidly with the femur. Weight-bearing on a pylon may be started in six weeks.

8. HIND-QUARTER (INTERINNOMINO-ABDOMINAL) AMPUTATION

The technique advocated by Surgeon Rear-Admiral Sir Gordon Gordon-Taylor is as follows.

The patient is turned slightly on to his sound side, with a sand-bag under the shoulder and another under the lower part of the thigh of the affected side. Blood transfusion is started before the operation begins.

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sion

An incision is carried along the crest of the ilium from behind the posterior superior spine to the anterior superior spine, and is then continued downwards and inwards one and a half inches below the inguinal ligament towards the middle of the origin of the adductor brevis. Where any doubt is experienced as to the fixity of a neoplasm to the inner aspect of the innominate bone, and as to the possibility of its removal, it is well straightway to cut through the flat muscles of the abdominal wall at or above their attachments to the iliac crest, and to satisfy oneself at once about the pathological integrity of the peritoneum and other structures before proceeding to deal with the external iliac vessels. When no such doubts are felt, it may be of some comfort to the operator to deal with the external iliac vessels as soon as the first incision is made. The inguinal ligament is divided at each end and at the inner pillar of the external abdominal ring, thus allowing the spermatic cord to be drawn out of harm's way. The insertion of the rectus abdominis to the pubic crest is next divided, and, after the anterior and posterior surfaces of the pubic bone have been cleared by blunt dissection, the symphysis pubis is divided by knife, or if necessary by saw.

econd
ncision

The patient is then very gently turned farther over on to his sound side and an incision carried from the mid-point of the iliac crest down to the gluteal

fold, which is followed to meet the lower and medial extremity of the first incision in the cruro-scrotal sulcus. The dorsum ilii is exposed and sawn through into the sciatic notch; this manoeuvre is simpler and more expeditious than attempting to disarticulate at the sacro-iliac synchrondrosis. If it is necessary, the small piece of the auricular surface of the ilium can be rapidly detached afterwards.

Further steps

The anterior and posterior bone sections being now complete, the innominate bone and lower extremity can be drawn away from the pelvic peritoneum and its contents.

The lumbo-sacral cord, the first and second sacral and the obturator nerves can all be identified, and injected with procaine hydrochloride before division. The obturator artery, the gluteal artery, the sciatic artery and probably the internal pudendal artery, can be secured before division, and in this manner the haemorrhage can be greatly minimized.

The psoas is cut through above the pelvic brim, and the division of the pyriformis and the levator ani and the detachment of the ischiocavernosus and crus penis from the ischio-pubic ramus liberate the innominate bone from the last fibromuscular links which fetter it to the underlying structures; the limb and the innominate bone are free.

All bleeding is now controlled and the peritoneum reinforced by the suture of the remains of the gluteus maximus, levator ani, etc. to the flank muscles and rectus abdominis. The skin is then sutured with interrupted stitches.

Retention of urine may follow the operation.

Precautions

The most important points in the conduct of the operation would appear to be: (1) the most gentle care should be taken in turning the patient; the danger from rough or excessive movement of a patient under spinal anaesthesia cannot be exaggerated; (2) blood transfusion should be started at the same time as the operation; (3) the division of the posterior portion of the dorsum ilii with the saw is more expeditious and simpler than disarticulation of the bone at the sacro-iliac synchondrosis and (4) haemorrhage should be minimized by preliminary control of the vessels before their division, and shock should be minimized by nerve-blocking before the trunks are sectioned.

9. FORE-QUARTER (INTERSCAPULO-THORACIC) AMPUTATION

Professor Harry Platt advocates Littlewood's technique, which is as follows.

The patient is placed on his sound side close to the edge of the operating table. There are two flaps, a cervico-scapular and a pectoro-axillary, but they may vary according to the exact position of the disease.

First incision

A cervico-scapular flap is made, commencing at the clavicle near the outer margin of the sternomastoid attachment, carried along the clavicle, over the prominence of the shoulder, along the axillary border of the scapula to a point below the angle and then backwards to about two inches from the spine. A flap of skin and subcutaneous tissue is rapidly turned back; this exposes the posterior surface of the scapula with the muscles attaching it to the spine.

The trapezius and the latissimus dorsi are divided, then the levator anguli scapulae and the rhomboids, and lastly the scapular attachments of the serratus magnus and the omohyoid muscles. Three or four vessels may require

(5) Stokes-Gritti amputation

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Second incision

The patient is then very gently turned farther over on to his sound side and an incision carried from the mid-point of the iliac crest down to the gluteal

AMYLOID INFILTRATION (AMYLOIDOSIS)

By GEOFFREY HADFIELD, M.D., F.R.C.P.
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1. DEFINITION

25.] Amyloid is a structureless, highly refractile, acidophile glyco-protein found in the tissues as an insoluble gel and first appearing *between* the scanty cells of the delicate connective tissue which lies immediately below the endothelial lining of capillary blood-vessels.

2. PATHOLOGY

Its deposition is strictly extracellular and relentlessly progressive, eventually causing great thickening of blood-vessel walls by totally replacing the connective tissue of capillaries, the muscle and connective tissue of arterioles, small arteries, venules and small veins; the total mass of amyloid eventually becomes enormous, the affected organ or tissue becoming symmetrically enlarged, heavy, rigid and translucent, and suffering great loss of its specific parenchyma from pressure atrophy.

3. TYPES

There are two varieties of amyloid infiltration.

Secondary (visceral) type

Secondary or visceral amyloidosis, by far the more common type, affects the capillaries and small blood-vessels of groups of organs, especially those which are rich in reticulo-endothelium. It appears first in the spleen, then the liver, and affects the kidney in 85 per cent of cases; the adrenal cortex is frequently involved, the pancreas not infrequently, and fairly often the mucous membrane of the small intestine.

Aetiology

In these situations it is a complication of any long-continued infection accompanied by serious loss of body protein from widespread tissue destruction with or without chronic suppuration. It may complicate the tissue destruction produced by a new growth or a reticulosis.

Primary mesodermal type

The second variety—primary mesodermal amyloidosis—is very rare and arises quite independently of tissue destruction, protein loss or chronic infection. Large quantities of amyloid are found in the myocardium, subcutaneous

ligature—branches of the suprascapular and posterior scapular arteries. The soft tissues are now separated from the clavicle close to the sternomastoid attachment, and the bone surrounded by a Gigli's saw and divided.

After division of the subclavius muscle the whole upper extremity falls away from the trunk, held by the subclavian vessels and the cords of the brachial plexus, which are fully on the stretch, standing out and easily seen.

The cords of the brachial plexus are divided with a pair of scissors close to the spine. An injection of procaine hydrochloride into each may be given before division to lessen shock.

Clips are applied to the subclavian artery which is divided between them; the vein is then seen and treated in the same way.

Second incision

The anterior or pectoro-axillary flap is now cut and reflected as far forwards as necessary.

Final stages

The last stages in the operation consist in the division of the pectoralis major and minor muscles, the position of the division depending upon the extent of the muscles which it may be thought necessary to remove.

After the division of these muscles the fore-quarter is removed. This exposes the thoracic boundaries of the axilla and the posterior triangle, so that it is now quite easy to remove any diseased lymphatic glands.

The flaps are sutured and a firm dressing is applied.

10. CINEPLASTIC AMPUTATIONS

These aim at isolating muscles in the stump and harnessing them to an artificial hand. A tunnel is made through the muscle and lined with skin and a rod is passed through the tunnel.

Cineplastic amputations were tried in Great Britain, and to a much larger extent in Italy, after World War I, and in both countries the operation has been abandoned. Various reasons have been assigned for the failure, in particular poor surgical technique and too heavy a limb. It has been urged that, with the advance in plastic surgery and the introduction of light metal alloys, the procedure should be given another trial in Great Britain. Surgeons are not in favour of further experimentation. They argue that the cineplastic amputee cannot perform as many functions as can the ordinary amputee. The cineplastic enthusiasts agree, but they claim that the cineplastic amputee has better control of what movements he can make.

To form an unbiased judgment one would need to examine and compare the capabilities of a number of amputees, some with ordinary limbs and some with cineplastic limbs. A certain number of cineplastic amputations are being done in the United States of America and elsewhere, and until he is in a position to examine the results, the British surgeon had better forego the pleasure of trying out the operation. Success will depend to a great extent upon development of suitable cineplastic limbs, a matter which requires prolonged research.

[References to other titles are given under Amputations in the Index Volume. The subject of Amputation is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 378.]

(2) Renal involvement

Renal involvement is more serious but, in spite of considerable and continuous albuminuria, oedema does not usually appear until the terminal phase, and both azotaemia and hypertension are not conspicuous. It is therefore probably correct to regard secondary amyloidosis as an index of the severity of tissue destruction and protein loss, and as a contributory rather than a direct cause of death. Severe renal amyloidosis alters prognosis because it is responsible for additional loss of plasma albumin and globulin by the urine, the globulin loss being proportionately much higher than in nephritis. The kidneys are involved in 85 per cent of cases of visceral amyloidosis. The urine is pale, clear, and of consistently low specific gravity. It contains from 1 to 2 per cent of protein and a moderate number of epithelial and granular tube casts. Hyaline casts are usually present but, contrary to an old belief, they do not contain amyloid. The kidney shows progressive deposition of amyloid *starting in the glomerular capillaries and the intertubular capillary plexus* and spreading to the interlobular arteries. There is always some degree, often a serious degree, of fatty degeneration, necrosis and desquamation of the secretory epithelium of the tubules accounting for the inability of the amyloid kidney to secrete a concentrated urine.

Oedema

Azotaemia

Incidence

Urinary findings

Course

Destruction of tubules

(3) Diagnosis

Amyloid possesses a marked capacity to combine with or adsorb various substances in solution in the plasma, and this may account for the well-known *variations in its chemical composition. It is the only extracellular* hyaline substance which freely adsorbs and thereby becomes tinted by congo red. Its affinity for this dye is remarkable. The amyloid in the spleen, kidneys and adrenals may still be dull red in colour to the naked eye at post-mortem examinations on patients given an injection of congo red two months before death. If 15 cubic centimetres of a 0·75 per cent aqueous solution of congo red be injected intravenously into a normal subject, considerable amounts of the dye can still be found in the circulating blood ten hours after the injection, and not more than 30 per cent disappears within an hour. In visceral amyloidosis little or no dye can be detected in the plasma two hours after injection, and 40 to 60 per cent of it disappears within an hour. In at least 60 per cent of advanced visceral *amyloidosis there is 100 per cent adsorption of* the dye in one hour. The use of congo red in the diagnosis of amyloidosis is fairly reliable, but as a routine test it occasionally gives an unexplained false positive, and rather more frequently a false negative result. Congo red has largely replaced the aniline dyes for the histochemical detection of amyloid in tissues. It should certainly be the method of choice for staining material obtained by liver puncture for diagnosis.

Adsorption of congo red

Reliability

(4) Nature and mode of formation

The nature and mode of formation of amyloid are complex problems. Recent investigations have shown that it contains two proteins not present in normal tissues or normal plasma, together with a sulphate-bearing polysaccharide fraction similar to, but by no means identical with, the chondroitin-sulphuric acid of normal cartilage on the one hand and with heparin on the other. A mixture of chondroitin-sulphuric acid and serum *in vitro*

Two proteins

Polysaccharide

Chondroitin-sulphuric acid

tissues, lungs, mucous membranes and lymph glands. It may form large tumour-like masses in the larynx and tongue, in the latter situation producing gross macroglossia. Another variety of amyloidosis complicates a considerable proportion of all cases of multiple myelomatosis with Bence-Jones proteinuria. It is probably of fundamental significance that this disease is not infrequently accompanied by hyperglobulinaemia.

Hyperglobulinaemia

4. SECONDARY (VISCERAL) AMYLOIDOSIS

Incidence

Tuberculosis

Actinomycosis

Fifty years ago this was a common complication of bone and joint tuberculosis, of chronic suppurative osteomyelitis and of the chronic tissue destruction of intractable tertiary syphilis. It is now almost confined to sanatoria treating cases of advanced progressive pulmonary tuberculosis but still complicates a considerable number of cases of actinomycosis. It must be borne in mind, however, that this, the common type of amyloidosis, has been described in a large variety of apparently unrelated diseases; that the preceding tissue destruction has varied considerably in degree; that although many months of free suppuration usually precede its development the period may be as short as six months, and that it still escapes clinical diagnosis in at least 70 per cent of cases. The surgeon should therefore seriously consider the likelihood of amyloidosis whenever the stage is set for its development for there is little doubt that radical surgery at an early stage may lead to its retrogression.

Plasma-albumin fall

Plasma-globulin rise

Classical triad of signs

Given continuous tissue destruction on a relatively large scale over a period measured in months, a significant fall in the albumin content of the plasma, together with an absolute or relative increase in the plasma-globulin, is enough to justify a diligent search for confirmatory evidence of early amyloidosis. There is no doubt that when clinical diagnosis is based on the traditional triad of clinical signs—chronic suppuration, enlarged liver and albuminuria—the number of cases diagnosed during life is never more than 10 per cent and the diagnosis is then made too late to justify radical surgery.

(1) Relation to pulmonary tuberculosis

Progressive cavitation

Recent statistics show that amyloidosis is present *post mortem* in 40 per cent of all fatal cases of pulmonary tuberculosis. The incidence is at least as high and probably higher in neglected cases of bone and joint tuberculosis. In pulmonary tuberculosis it is far commoner in cases of progressive cavitation, and especially if this is accompanied by pyopneumothorax or empyema, laryngeal involvement, and ulceration of the ileum. Approximately 90 per cent of all patients are dead within two years of clinical diagnosis, 60 per cent within six months and 80 per cent within a year.

Prognosis

Effect on function slight

May death be directly attributed to amyloidosis? To what extent is it contributory, and how does its development alter prognosis? These are difficult questions, but it must be remembered that even with extensive infiltration the effect on function is almost unbelievably slight, and in spite of gross infiltration of blood-vessel walls the endothelium invariably survives and thrombosis is never found. Liver function remains remarkably good, and serious involvement of the adrenals produces some of the manifestations of Addison's disease in a small percentage of cases only.

(2) Renal involvement

Renal involvement is more serious but, in spite of considerable and continuous albuminuria, oedema does not usually appear until the terminal phase, and both azotaemia and hypertension are not conspicuous. It is therefore probably correct to regard secondary amyloidosis as an index of the severity of tissue destruction and protein loss, and as a contributory rather than a direct cause of death. Severe renal amyloidosis alters prognosis because it is responsible for additional loss of plasma albumin and globulin by the urine, the globulin loss being proportionately much higher than in nephritis. The kidneys are involved in 85 per cent of cases of visceral amyloidosis. The urine is pale, clear, and of consistently low specific gravity. It contains from 1 to 2 per cent of protein and a moderate number of epithelial and granular tube casts. Hyaline casts are usually present but, contrary to an old belief, they do not contain amyloid. The kidney shows progressive deposition of amyloid starting in the glomerular capillaries and the intertubular capillary plexus and spreading to the interlobular arteries. There is always some degree, often a serious degree, of fatty degeneration, necrosis and desquamation of the secretory epithelium of the tubules accounting for the inability of the amyloid kidney to secrete a concentrated urine.

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ANAESTHESIA—GENERAL

By ARCHIBALD D. MARSTON, M.R.C.S., D.A.
Senior Anaesthetist, Guy's Hospital; Lecturer on Anaesthesia, Guy's Hospital Medical School, London

1. DEFINITION AND NOMENCLATURE

26.] When Oliver Wendell Holmes invented the word "anaesthesia" to describe a condition in which operative measures were free from pain, only nitrous oxide and ether were in existence, and these agents produced a state of unconsciousness in addition to analgesia. Since then numerous agents have been introduced, and the term anaesthesia no longer describes the effects of them all.

Anaesthesia and surgical anaesthesia

There is an important difference between anaesthesia and surgical anaesthesia, because in the latter state the patient will not move when stimulated, although complete freedom from pain exists in both. Analgesia gives freedom from pain without loss of consciousness, and may be general or local in its administration and effects.

develops properties similar to that of amyloid, whilst a mixture of serum and heparin gives a positive formol-gel reaction, an increase in the sedimentation rate and a positive Takata-Ara reaction. These reactions are found in human diseases accompanied by a relative or absolute increase in plasma globulin. Amyloidosis has been produced experimentally in animals, especially the mouse, by repeated injection of bacteria, sterile bacterial toxins, non-toxic foreign proteins, sodium caseinate, and, more recently, by pentnucleotides. Under these conditions, the amyloidosis is usually, if not always, associated with hyperglobulinaemia. In most patients suffering from multiple myelomatosis there is hyperglobulinaemia of normal γ-globulin and amyloidosis is a fairly frequent complication. The exact frequency of hyperglobulinaemia in amyloidosis is difficult to assess but it appears to be common; it is usually associated with chronic albumin loss and may be absolute or relative.

Heparin

Takata-Ara reaction

Hyperglobulinaemia

[References to other titles are given under Amyloid Disease in the Index Volume. The subject of Amyloid Disease is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 401.]

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Anaesthesia and surgical anaesthesia

There is an important difference between anaesthesia and surgical anaesthesia, because in the latter state the patient will not move when stimulated, although complete freedom from pain exists in both. Analgesia gives freedom from pain without loss of consciousness, and may be general or local in its administration and effects.

All anaesthetics and analgesics produce a varying degree of partial amnesia or forgetfulness of the immediate past, and this effect may be enhanced by the administration of drugs such as Omnopon and scopolamine (twilight sleep), and certain of the derivatives of barbituric acid such as Nembutal.

Nature of anaesthesia

Although the precise details of the nature of anaesthesia are not known, it has been noted that the cells of the central nervous system are affected in reverse order to their development. The theory of oxygen replacement in the cells of the central nervous system has been generally recognized as the most probable cause of anaesthesia; it may be produced by physical or chemical means. The metabolic rate of the nerve cells first affected by anaesthesia is much higher than that of those of earlier development, and this supports the theory of oxygen deprivation, which is a reversible process whereby cells responsible for pain reception and consciousness are robbed of sufficient oxygen to produce anaesthesia, whilst the primitive cells of lower metabolic rate are able to support respiration and circulation and allow life to proceed.

2. STAGES OF ANAESTHESIA

The classification of A. E. Guedel, which is generally recognized as being the best, describes four stages, of which the third is divided into four planes.

Stage 1—analgesia.
Stage 2—unconscious excitement.
Stage 3—surgical anaesthesia.
  Plane 1—light anaesthesia.
  Plane 2—surgical anaesthesia.
  Plane 3—deep anaesthesia.
  Plane 4—profound anaesthesia.
Stage 4—respiratory paralysis.

3. SURGICAL USES OF VARIOUS STAGES

Stage 1 is used for surgical dressings of a painful nature.

Stage 2 has no surgical uses.

Stage 3, *Plane* 1.—This suffices for many extraperitoneal operations. It is usual in these cases first to attain a deeper plane and then to lighten the anaesthesia. This plane may be used in intraperitoneal work during excision and stitching of visceral peritoneum, the plane of anaesthesia being deepened before the parietal peritoneum is closed. Trauma of the visceral peritoneum is associated with few painful afferent stimuli, but in the case of parietal peritoneum these are multiple and severe.

Plane 2.—Adequate anaesthesia for the great majority of surgical operations is secured in the deepest part of this plane.

Plane 3.—Although sufficient muscular relaxation is usually obtained in Plane 2, the quieter respiration of Plane 3 is an advantage in enabling the surgeon to carry out difficult intraperitoneal techniques such as the excision of a gall-bladder, operations on the common bile-duct or for a perforated ulcer.

Plane 4.—This plane is seldom of any advantage in abdominal operations, because a maximum of muscular relaxation has already been obtained and the gasping type of diaphragmatic breathing is a hindrance because the abdominal viscera tend to be extruded. In response to requests by the surgeon for more comfortable operating conditions, a common mistake of the inex-

perienced anaesthetist is to push the patient still deeper into Stage 4 with all its great dangers. The proper course is deliberately to *lighten* the anaesthesia and secure the better type of respiration found in the late part of Plane 2 or the early part of Plane 3.

Stage 4.—This stage is seldom entered except by accident, and should be avoided at all times because of the imminent danger of a fatal collapse. Even if no fatality occurs, there is still the danger of untoward after-effects. In certain operations in thoracic surgery a temporary cessation of respiration is extremely useful, and this is usually obtained by the use of cyclopropane with a high percentage of oxygen.

4. SIGNS OF ANAESTHESIA

Depth of anaesthesia

It is important that the exact depth of anaesthesia be known at any time during the operation. The anaesthetist can only accomplish this by practical experience and an exact knowledge of the established signs of anaesthesia and their relation to the stages and planes classified by Guedel.

Groups of signs

Three groups of signs are commonly described and are known as *eye* signs, *respiratory* signs and *muscle* signs. No single group is infallible, and the signs must always be considered in combination.

(*a*) *Eye signs*

(i) *The eyeball.*—In the first two stages, the eyeball moves about and there is a moist lacrimal secretion, but at the commencement of the third stage the eyeball becomes still and centrally placed, and lacrimal secretion decreases as anaesthetic depth increases.

(ii) *Conjunctival reflex.*—If the palpebral fissure is opened and the conjunctiva touched with the finger or blown upon and the eyelids do not close, the patient is anaesthetic and in the first plane of the third stage.

(iii) *Corneal reflex.*—If the cornea is lightly touched and no response occurs, the second plane of the third stage has been reached and the patient is surgically anaesthetic.

(iv) *Light reflex.*—This is the least exact of the eye signs because premedication and the exhibition of various anaesthetic agents affect this reflex in various ways, the main tendency being for the iris diaphragm to dilate in the first two stages, then to become small and finally to become very large in the deeper planes of Stages 3 and 4.

Method of observing light reflex

The best way to observe the light reflex is to close both eyelids for half a minute and then to open one palpebral fissure, note the pupil and, whilst so doing, open the other eyelid. Contraction of the iris on exposure to light will become less brisk as anaesthesia deepens and will become absent in the third plane of the third stage.

It may be taken as a general rule that a widely dilated pupil with no light reflex indicates an unnecessary depth of anaesthesia, and is a definite warning that the dangerous fourth stage is nearly if not quite reached.

(*b*) *Respiratory signs*

During the first two stages, the respiratory centre passes from the control of the higher nervous centres and becomes automatic at the commencement of the third stage. The breathing becomes both deeper and more frequent and reaches the height of a crescendo in the second plane, at the termination of which a diminuendo starts, while in the first part of the third plane the most

tranquil respiratory phase occurs. During the latter part of Plane 3 the intercostal muscles become progressively more inactive from above downwards. In Plane 4 the respiration has lost its thoracic character, and has become mainly diaphragmatic. The automatic character of respiration is lost in ratio to this change in respiratory muscular action, and at the start of Plane 4 becomes progressively triphasic in character, each respiration consisting of an inspiration, a pause and then an expiration. As anaesthesia deepens, the interval between inspiration and expiration becomes progressively lengthened, and this spasmodic, dangerous and surgically unsuitable type of respiration proceeds into Stage 4 and if unchecked will lead to a fatal termination.

Muscle signs

(c) *Muscle signs*

During the early second stage, muscular action passes from voluntary control, while during the first and second planes of Stage 3 progressive relaxation is the general rule, proceeding to a maximum in the third plane of this stage.

Degree of relaxation

Some indication of the degree of muscular relaxation attained may be gauged by depressing the mandible or by turning the head from side to side; both these manoeuvres, if easily carried out, indicate adequate muscular relaxation for operative or manipulative procedures.

5. PREPARATION OF PATIENT

Except for acute conditions, patients should be admitted at least sixteen hours before operation, so that a routine examination may be carried out by the anaesthetist, premedication ordered and a choice of anaesthetic made.

In the case of elderly, frail or tired people, two or three days' rest in bed is of real value, and in cases in which post-operative pulmonary complications are feared the patient may be taught breathing exercises and be encouraged to continue with them as soon as possible after operation.

Diet

On the day before operation, light meals and plenty of fluids should be ingested. Barley-sugar drops may be prescribed or glucose given with the fluids. On the morning of operation a cup of tea with a biscuit or a small piece of toast may be taken three hours before operation. Should the operation be postponed to the afternoon, a cup of soup or Bovril with a little toast may be taken half an hour before noon. If the operation is to take place in the late afternoon, a light lunch is taken at noon, and a cup of tea and a biscuit three hours before operation. In the ideal preparation the patient has an empty stomach, no tissue dehydration and no shortage of glycogen in the liver at the time of administration of a general anaesthetic.

Drastic purgation is to be deprecated, and gentler measures for clearing out the intestines than has been the usual practice are now advised.

Clothing

Under anaesthesia the heat-regulating mechanism of the body is largely put out of action, and warm but loose clothing should be supplied to all areas except the site of operation.

(1) Examination

Oral cavity

The oral cavity should be carefully examined for loose or crowned teeth, artificial dentures and any gross dental sepsis. If the last-named is present, it should be reported to the surgeon, as its existence will predispose to post-operative pulmonary complications.

Veins

If intravenous basal narcosis is to be used, the antecubital fossae are

examined for suitable veins, and a quick examination made to exclude the presence of an aberrant artery.

(2) *Premedication*

Modern anaesthetists recognize the value of "balanced anaesthesia" which was first advocated by Dr. Lundy of the Mayo Clinic. This entails a recognition of the value of the synergistic action of drugs. If a number of drugs are used to produce general anaesthesia, the sum total of their action is increased, and the anaesthesia has a *tranquillity, efficiency and controllability* unattained by reliance on a single drug.

Balanced anaesthesia

The usual modern practice is as follows: (a) premedication, (b) basal narcosis, (c) maintenance anaesthesia.

When indicated, a fourth factor is added—local or regional analgesia, which *reinforces muscular relaxation and places a barrier between nociceptive* afferent impulses and the areas of pain reception in the central nervous system.

The first measure in premedication is to ensure a good night's sleep, for which one of the following is commonly prescribed:

Sleep

Medinal (soluble barbitone)	5 to 10 *grains*
Veronal (barbitone)	2 to 7 grains
Allonal	1 to 2 tablets
Phanodorm (Phanodorn N.N.R.)	1 to 2 tablets
Nembutal (Pentobarbital Sodicum *U.S.P.* XII)	1 to 2 capsules each containing $1\frac{1}{2}$ grains
Dial (allobarbitone)	1 to 2 tablets

A useful cachet, which may be repeated during the night if required, is composed of aspirin 5 grains and Veronal 2 grains.

The use of Omnopon $\frac{1}{3}$ grain and scopolamine (hyoscine) $\frac{1}{150}$ grain is deservedly popular; this is given subcutaneously a full hour before operation. The patient is rendered sleepy and tranquil and will develop a partial amnesia. *There is no need to give atropine in addition to scopolamine, as the* drugs have a similar effect on the respiratory system. The usual alternative is morphine $\frac{1}{6}$ grain to $\frac{1}{4}$ grain, and atropine $\frac{1}{100}$ grain. These drugs do not support each other so adequately as Omnopon and scopolamine, but do not depress the respiratory centre so much. Recognizing this, the anaesthetist will reserve the less efficient but safer morphine and atropine sequence for bad-risk cases.

Pre-anaesthetic injection

6. BASAL NARCOTICS

The introduction of basal narcosis is perhaps the greatest contribution anaesthesia has made to modern surgery. Induction of anaesthesia is rid of its former terrors, and *it is a notable fact that patients* who have had a basal narcotic seldom dread a repetition of the experience. There is an absence of struggling, with its strain on the respiratory and circulatory systems, and a minimal degree of disturbance of endocrine function (Marston, 1938).

Nitrous oxide and oxygen often prove sufficient to complete the balance of anaesthesia, and this is indeed an advantage since research *and clinical* experience have shown this combination to be the least harmful of all anaesthetic agents. This, however, is true only if nitrous oxide is administered with

sufficient oxygen to supply the minimal metabolic needs of the body, and this is easily possible in conjunction with basal narcosis. At the Mayo Clinic 50 per cent oxygen and 50 per cent nitrous oxide have been used with great success in combination with continuous administration of Pentothal Sodium. (Annual report of the Section of Anaesthesia, 1942.)

Effects of basal narcotics

The basal narcotics are not universally applicable. With the exception of paraldehyde, they all lower the blood-pressure, depress the respiratory centre and render the reflexes of the upper respiratory tract less brisk than usual. Thus in wasting diseases, shock, asthenic states, anaemia and abnormally low blood-pressure, and in those operations which require a quick return of the laryngeal reflex, basal narcotics must be used with caution (Marston, 1942).

The effects of shock are increased in deep basal narcosis, and recovery may be retarded. This may be due to depression of the respiratory centre and, if pulmonary ventilation is inadequate, sequelae such as massive collapse or hypostatic congestion may occur.

There are many basal narcotics, the three most usual groups being:

Groups of basal narcotics

Group 1—bromethol (Avertin).

Group 2—paraldehyde.

Group 3—derivatives of barbituric acid: (a) Nembutal, (b) Soneryl Sodium, (c) Evipan Sodium (soluble hexobarbitone), (d) Pentothal Sodium, (e) Narconumal.

Routes of administration

Basal narcotics may be administered orally, per rectum, or intravenously. On no account should these drugs be given by more than one route in a single *administration on account of the risk of overdose.*

(1) **Bromethol (Avertin)** (Tribromœthanol, *U.S.P.* XII)

This drug, having the formula CBr_3CH_2OH (tribromethylalcohol), is prepared by the reduction of bromal with yeast. It is a white crystalline substance, and when dissolved in amylene hydrate forms a syrupy fluid which contains one gramme of solid Avertin per cubic centimetre.

(i) *Dosage.*—The dose ranges between 0·08 and 0·12 gramme per kilogram of body-weight for surgical cases. The average dose, sometimes known as the Bayer Standard Dose, is 0·1 gramme per kilogram of body-weight.

Reliance on the weight rates will not give the best results. It is necessary to examine the patient, and only experience will enable the optimal dose to be found. Clinical experience has shown that young people need more than old, obese subjects less than thin ones, and nervous people more than those of placid temperament. In wasting diseases, when any extensive dehydration of tissues has occurred, it is usual to give a smaller dose, *and 0·08 gramme per* kilogram of body-weight should not be exceeded. It is easy to overdose obese people, *especially those over 15 stone in weight. In these cases* satisfactory results are obtained if the 0·1 gramme per kilogram dose for 12 stone 2 lb. (77·16 kilograms) is given, however much the weight may exceed this figure.

(ii) *Dispensing.*—This is usually carried out by a pharmacist and the solution supplied in a vacuum flask at body heat. If the anaesthetist essays this task, he must be careful not to overheat the solution. Avertin becomes soluble at body heat, and at 105° F. decomposes with the production of hydrobromic acid and

dibromacetaldehyde, the presence of which will cause pain or discomfort to the patient and possibly local damage to the bowel.

Thus an obligatory test must be carried out before use. This test consists of the addition of two drops of congo red to 5 cubic centimetres of the solution. If the colour remains orange red, all is well; but if a dull blue colour results, the solution must be discarded.

Solution test

Distilled water must always be used for mixing Avertin and for producing the 2·5 per cent solution required.

(iii) *Administration.*—This is carried out with an air-free tube and funnel. The catheter may be of small diameter to minimize discomfort. Three-quarters of the dose is given slowly during five minutes; if the patient sleeps during the next ten minutes, no more Avertin is given; if he does not sleep, the remaining portion of the solution is then administered. Narcosis reaches its maximum in thirty minutes and will continue in a diminishing degree for from two to four hours. Avertin is excreted by the kidneys after detoxication by combination with glycuronic acid (Endoh).

Shivering may sometimes be observed during recovery. This is usually transitory, and the patient should be covered with warm blankets.

(iv) *Indications.*—Although largely displaced in recent years by intravenous injections of the barbituric derivatives, Avertin remains the basal narcotic of choice in the case of toxic goitre, and combinations of this drug with maintenance anaesthesia by means of nitrous oxide or cyclopropane and oxygen and with local or regional analgesia produce a balanced anaesthesia which is both safe and efficient.

If no visible veins exist, Avertin is a suitable alternative to intravenous narcosis, and also for nervous subjects who dread any needle puncture.

(v) *Contra-indications.*—There are few contra-indications to Avertin, which has secured a well-deserved reputation for safety and reliability. Avertin should be avoided in cases of hepatic insufficiency, shock, haemorrhage, respiratory obstruction or low basal metabolic rates, and should be used with caution, and in small dosage in low-blood-pressure states and renal disease.

Avertin cannot be efficiently used in cases of rectal incontinence, and is not usually employed for operations in or around the anus, rectum or perineum.

(2) Paraldehyde

This drug, having the formula $(C_2H_4O)_3$, is a polymer of acetaldehyde. It is administered rectally, with the patient in the left lateral posture, about three-quarters of an hour before operation.

(i) *Dosage.*—The normal dose is from half to one drachm per stone (0·3 to 0·6 cubic centimetre per kilogram) body-weight, with a maximal dose of 8 drachms. If larger doses are accidentally prescribed, symptoms of overdose with respiratory failure and a fatal termination may occur.

If a patient's weight is in excess of 8 stone, the drug may be combined with injections of morphine, Omnopon and hyoscine, given separately or in combination. This technique has been described in detail by Rowbotham (1928).

In combination with morphine

(ii) *Dispensing.*—Paraldehyde is cheap and easy to dispense, being mixed with normal saline to form a 10 per cent solution.

(iii) *Indications.*—This drug has little effect on either respiration or circulation, and is indicated in cases of unduly high or low blood-pressure,

in wasting diseases, in asthenic states with a low basal metabolic rate, and for operations in which a brisk reflex is desirable in the upper respiratory passages. It is especially indicated as a basal narcotic for the removal of tonsils and adenoids in weakly and nervous children, the cough reflex being unaffected by the drug.

Errors in dosage

(iv) *Disadvantages.*—Errors in dosage have unfortunately been more frequent with paraldehyde than with other basal narcotics, the usual mistake being to dispense ounces instead of drachms, thus leading to a fatality. In our opinion, paraldehyde solutions should *always* be dispensed from a *written prescription* and by a qualified dispenser.

Odour

Paraldehyde is largely excreted by the respiratory system and, as the drug has an unpleasant odour, this may be displeasing to relatives and friends. The patient, fortunately, is quite unaware of any disagreeable effects.

Variable results

Although paraldehyde narcosis is usually successful in children, it is variable in adults and, unless specially indicated, is better replaced by Avertin or one of the derivatives of barbituric acid.

(3) Derivatives of barbituric acid

Sodium Amytal, Nembutal and Pernocton (Pernoston) have been abandoned in favour of the more quickly excreted preparations known as Evipan, Pentothal Sodium and Narconumal. The most popular of these is Pentothal Sodium, which is used more frequently than any other basal narcotic.

(*a*) *Pentothal Sodium—sodium thiopentobarbital, thio-barbiturate 8064, Thiopentonum Solubile, B.P.*

This is a yellow powder supplied in glass containers of 0·5 gramme, and 1 gramme. If 10 cubic centimetres of distilled water is added to 1 gramme of Pentothal, a 10 per cent solution results. This concentration was extensively used when the drug was first introduced, but it is now generally recognized to be too high, as it not only robs the drug of easy control, but in the event of tissue leakage the damage may be severe. Five per cent solutions are made by mixing 1 gramme with 20 cubic centimetres of water and 0·5 gramme with 10 cubic centimetres of water; this affords a more easily regulated induction, and in the event of leakage the effect is usually slight. A concentration of 2·5 per cent is sometimes used for continuous administration.

Dosage

(i) *Indications.*—The drug may be used as a basal narcotic or as a complete medium for anaesthesia. Induction is simple for the anaesthetist, pleasant for the patient, and gives a satisfactory muscular relaxation for the surgeon.

(ii) *Contra-indications.*—These are as follows.

(1) Respiratory obstruction.
(2) Acute respiratory disorders.
(3) Hepatic insufficiency.
(4) Varicose veins.
(5) Absence of surface veins.
(6) Cardiac embarrassment.
(7) In severe shock, unless used with caution as regards rate of administration and dosage.
(8) In severe blood loss, unless anaemic anoxia be avoided by oxygen therapy.

Method of administration

(iii) *Administration.*—A sharp needle with a 45° bevel should be employed. Intravenous puncture is best made at the junction of two veins. The skin

should be pierced with a minimal degree of angulation of the needle, in fact as nearly parallel with the skin as possible. The common error is to allow the needle to progress through the posterior wall of the vein. To avoid this, the following technique is advised.

Special technique

(1) Puncture the skin and enter the vein; observe the blood coming back into the syringe.

(2) Reduce angulation so that the syringe is now parallel with the skin surface. Push the needle 2 millimetres forward, then aspirate blood back into the syringe. Now commence the injection with the needle safely in the lumen of the vein.

Another hint of value is always to have the eye of the needle downwards, and to make the entrance to the vein along its long axis.

(iv) *Dosage*.—Lauber's original method entailed making the patient count until consciousness was lost, then to pause, then to give a further dose equal to that already given. Psychiatrists consider the counting method to be a poor psychological approach. They suggest asking the patient to relax, the anaesthetist then giving the Pentothal whilst maintaining a steady flow of reassuring remarks. The latter method is, in our opinion, the better, and does away with an ordeal complex.

Induction

The Pentothal should be given slowly at the rate of 1 cubic centimetre per ten seconds until 4 cubic centimetres have been given. A pause of forty-five seconds should then be made, to allow the drug to disperse into the central nervous system. During this pause consciousness is lost and surgical anaesthesia is commonly attained. If single-dose anaesthesia is desired for a period up to fifteen or twenty minutes, a further 3 to 4 cubic centimetres are slowly injected.

Preceding maintenance anaesthesia

If it is desired to precede maintenance anaesthesia by basal narcosis, the administration of 2 cubic centimetres following the safety pause is all that is usually required. As Pentothal depresses the respiratory centre, nothing is gained by giving heavy initial doses of basal narcotic, since steady respiration is essential to allow maintenance inhalation to proceed smoothly. If this precaution is not observed, the patient may come round from the Pentothal before the effect of the maintenance anaesthetic has become established.

(v) *Continuous Pentothal injection*.—Once induction with the 5 per cent solution has been achieved, a 2·5 per cent solution may be used for

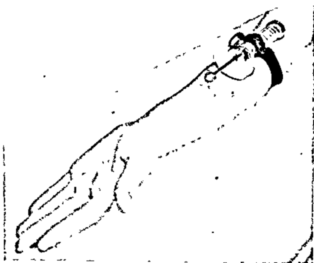


FIG. 74.—Magill's third hand. (*Medical and Industrial Equipment Ltd.*)

maintenance. Apparatus for this technique is readily available, and the best results are obtained from those of simple construction. For short operations, 1 gramme of Pentothal may be contained in a 20 cubic centimetre Record syringe attached to the arm by I. W. Magill's "third hand," of which an illustration is here shown (Fig. 74).

For longer operations, the apparatus of Macintosh and Pask enables intravenous administration to proceed with efficiency and safety once the necessary experience has been gained; but this method should be employed only after a practical demonstration by an anaesthetist who is thoroughly conversant with it.

Oxygen with continuous Pentothal

It is generally recognized that oxygen should always be administered with continuous Pentothal, because the drug depresses respiration, and the 20 per cent oxygen content of the atmosphere is insufficient to prevent the onset of stagnant anoxia.

(vi) *Intra-arterial injection.*—If this accident occurs, peripheral gangrene results and amputation of the limb may be required. This happening can *always* be avoided if the following points are borne in mind.

(1) Aberrant vessels may be present in any patient.

(2) The injection must be made into a non-pulsating vessel. If a tourniquet has been applied, feel the radial pulse; if this is absent, remove the tourniquet and palpate the vessel to be punctured.

(3) Observe the colour of the blood aspirated back into the syringe—it should *not* be bright red in colour.

(4) If the patient complains of cramp and pain during injection, at once cease the administration.

(vii) *Summary.* To get the best results from Pentothal Sodium:

(1) use a 5 per cent solution for induction and a 2·5 per cent solution for continuous use;

(2) always have oxygen available, and always use it for continuous work;

(3) a safety pause is essential after the first 4 cubic centimetres have been administered;

(4) mix 2 cubic centimetres of nikethamide (Coramine) with each gramme of Pentothal to counteract respiratory depression.

(b) Hexobarbitone (Evipan)

Synonyms for this substance are: Evipan (Evipal), Cyclonal Sodium, Hexanastab, hexobarbitone soluble. Evipan is a white powder supplied in glass containers containing 1 gramme. This is mixed with 10 cubic centimetres of distilled water to form a 10 per cent solution. Compared with Pentothal, induction and recovery are slower, there is less relaxation of muscle, and muscular spasm and clonus may sometimes persist during the administration. There is less respiratory depression, and if leakage into the tissues occurs there is little local reaction.

There is no doubt that Pentothal is the better drug, but if venepuncture of a difficult vein is to be attempted by an inexperienced anaesthetist, Evipan is the safer choice.

Dosage

Dosage.—Four cubic centimetres are injected at a constant rate of 1 cubic centimetre per fifteen seconds, and consciousness is usually lost during a safety pause which should last for forty-five seconds. If basal narcosis is desired, the addition of a further 1 to 2 cubic centimetres will suffice.

For single-dose anaesthesia, *from 6 to 8 cubic centimetres will give from* fifteen to twenty minutes' anaesthesia. The maximal dose is 10 cubic centimetres of the 10 per cent solution.

Contra-indication

Evipan is not recommended for continuous administration, as doses in excess of 1 gramme cause a delayed recovery which may occasion anxiety.

(c) *Sodium ethylmethylbutylbarbiturate* (*Nembutal*) (*Pentobarbital Sodicum U.S.P. XII*)

Oral administration

This is a white powder with a slightly bitter taste, now usually given by the oral or rectal route.

The powder is generally dispensed in capsules containing 1½ grains. The capsules are made of keratin and should be pierced with a needle in several places before use.

Dosage

The dosage is as follows. (i) *For adults*, 2 capsules (3 grains) overnight; 2 to 3 capsules one hour before operation. (ii) *For children*, ½ a grain per stone of the body-weight, with a maximal dose of 3 grains. Children do not swallow capsules easily, and it is better to mix the powder with a little jam, honey or syrup.

Rectal administration

Nembutal may be administered to children as a rectal suppository, the dose *being twice the amount used orally and given twice as long beforehand. On no* account should oral or rectal Nembutal be followed by an intravenous barbiturate.

Indications

Irregular in action in the case of adults, it is not to be compared in efficiency with intravenous Pentothal or Avertin. In children it is of definite value, and is often used before operations for the removal of tonsils and adenoids.

(4) Treatment of overdose

*A clear airway is essential, and may be secured by the insertion of an arti*ficial airway (nasal catheter) or by traction on the lower jaw. Oxygen, or a mixture of oxygen 93 per cent and carbon dioxide 7 per cent, should always be available. The antidotes to Avertin are ephedrine and colonic irrigation with hypertonic sodium thiosulphate solution.

Antidotes

Picrotoxin (intravenous injection of 2 cubic centimetres of a 0·3 per cent solution) may be given in the case of paraldehyde or the barbiturates, but the analeptic solutions of camphor known as nikethamide, Coramine, Nikamide, Anacardone and Corvotone are more generally used.

In cases of urgency the nikethamide solution should be given intravenously in large doses (Coramine 5 to 10 cubic centimetres).

Lumbar puncture

Repeated lumbar puncture is sometimes of value in symptoms of overdose of the barbituric derivatives.

7. MAINTENANCE ANAESTHESIA

Maintenance anaesthetic agents are numerous, and each has special advantages and disadvantages. The modern anaesthetist should endeavour to choose the best agent for each individual and avoid routine administration.

(1) Chloroform

This is a heavy colourless liquid with a specific gravity of 1·485, and should be stored in coloured bottles not exposed to light, otherwise decomposition may occur with the formation of poisonous phosgene. Chloroform produces a pleasant non-irritating vapour and is not inflammable. These

Advantages and disadvantages

maintenance. Apparatus for this technique is readily available, and the best results are obtained from those of simple construction. For short operations, 1 gramme of Pentothal may be contained in a 20 cubic centimetre Record syringe attached to the arm by I. W. Magill's "third hand," of which an illustration is here shown (Fig. 74).

For longer operations, the apparatus of Macintosh and Pask enables intravenous administration to proceed with efficiency and safety once the necessary experience has been gained; but this method should be employed only after a practical demonstration by an anaesthetist who is thoroughly conversant with it.

Oxygen with continuous Pentothal

It is generally recognized that oxygen should always be administered with continuous Pentothal, because the drug depresses respiration, and the 20 per cent oxygen content of the atmosphere is insufficient to prevent the onset of stagnant anoxia.

(vi) *Intra-arterial injection.*—If this accident occurs, peripheral gangrene results and amputation of the limb may be required. This happening can *always* be avoided if the following points are borne in mind.

(1) Aberrant vessels may be present in any patient.

(2) The injection must be made into a non-pulsating vessel. If a tourniquet has been applied, feel the radial pulse; if this is absent, remove the tourniquet and palpate the vessel to be punctured.

(3) Observe the colour of the blood aspirated back into the syringe—it should *not* be bright red in colour.

(4) If the patient complains of cramp and pain during injection, at once cease the administration.

(vii) *Summary.* To get the best results from Pentothal Sodium:

(1) use a 5 per cent solution for induction and a 2·5 per cent solution for continuous use;

(2) always have oxygen available, and always use it for continuous work;

(3) a safety pause is essential after the first 4 cubic centimetres have been administered;

(4) mix 2 cubic centimetres of nikethamide (Coramine) with each gramme of Pentothal to counteract respiratory depression.

(b) Hexobarbitone (Evipan)

Synonyms for this substance are: Evipan (Evipal), Cyclonal Sodium, Hexanastab, hexobarbitone soluble. Evipan is a white powder supplied in glass containers containing 1 gramme. This is mixed with 10 cubic centimetres of distilled water to form a 10 per cent solution. Compared with Pentothal, induction and recovery are slower, there is less relaxation of muscle, and muscular spasm and clonus may sometimes persist during the administration. There is less respiratory depression, and if leakage into the tissues occurs there is little local reaction.

There is no doubt that Pentothal is the better drug, but if venepuncture of a difficult vein is to be attempted by an inexperienced anaesthetist, Evipan is the safer choice.

Dosage

Dosage.—Four cubic centimetres are injected at a constant rate of 1 cubic centimetre per fifteen seconds, and consciousness is usually lost during a safety pause which should last for forty-five seconds. If basal narcosis is desired, the addition of a further 1 to 2 cubic centimetres will suffice.

For single-dose anaesthesia, from 6 to 8 cubic centimetres will give from fifteen to twenty minutes' anaesthesia. The maximal dose is 10 cubic centimetres of the 10 per cent solution.

Evipan is not recommended for continuous administration, as doses in excess of 1 gramme cause a delayed recovery which may occasion anxiety. *Contra-indication*

(*c*) *Sodium ethylmethylbutylbarbiturate* (*Nembutal*) (*Pentobarbital Sodicum U.S.P. XII*)

This is a white powder with a slightly bitter taste, now usually given by the oral or rectal route. *Oral administration*

The powder is generally dispensed in capsules containing 1½ grains. The capsules are made of keratin and should be pierced with a needle in several places before use.

The dosage is as follows. (i) *For adults*, 2 capsules (3 grains) overnight; 2 to 3 capsules one hour before operation. (ii) *For children*, ½ a grain per stone of the body-weight, with a maximal dose of 3 grains. Children do not swallow capsules easily, and it is better to mix the powder with a little jam, honey or syrup. *Dosage*

Nembutal may be administered to children as a rectal suppository, the dose being twice the amount used orally and given twice as long beforehand. On no account should oral or rectal Nembutal be followed by an intravenous barbiturate. *Rectal administration*

Irregular in action in the case of adults, it is not to be compared in efficiency with intravenous Pentothal or Avertin. In children it is of definite value, and is often used before operations for the removal of tonsils and adenoids. *Indications*

(4) Treatment of overdose

A clear airway is essential, and may be secured by the insertion of an artificial airway (nasal catheter) or by traction on the lower jaw. Oxygen, or a mixture of oxygen 93 per cent and carbon dioxide 7 per cent, should always be available. The antidotes to Avertin are ephedrine and colonic irrigation with hypertonic sodium thiosulphate solution. *Antidotes*

Picrotoxin (intravenous injection of 2 cubic centimetres of a 0·3 per cent solution) may be given in the case of paraldehyde or the barbiturates, but the analeptic solutions of camphor known as nikethamide, Coramine, Nikamide, Anacardone and Corvotone are more generally used.

In cases of urgency the nikethamide solution should be given intravenously in large doses (Coramine 5 to 10 cubic centimetres).

Repeated lumbar puncture is sometimes of value in symptoms of overdose of the barbituric derivatives. *Lumbar puncture*

7. MAINTENANCE ANAESTHESIA

Maintenance anaesthetic agents are numerous, and each has special advantages and disadvantages. The modern anaesthetist should endeavour to choose the best agent for each individual and avoid routine administration.

(1) Chloroform

This is a heavy colourless liquid with a specific gravity of 1·485, and should be stored in coloured bottles not exposed to light, otherwise decomposition may occur with the formation of poisonous phosgene. Chloroform produces a pleasant non-irritating vapour and is not inflammable. These *Advantages and disadvantages*

virtues combined with its efficiency in producing muscular relaxation and a type of breathing suitable for surgical operations make it an excellent anaesthetic agent, but unfortunately these advantages are completely overshadowed by its immediate danger to life and its production of pathological after-effects which, although only occasionally fatal, may seriously affect the convalescence and recovery of the patient.

Indications for use

In the days when suitable alternative agents did not exist, there was a definite indication for its use in skilled hands; but now that alternative agents are available the only indication for the use of this toxic drug is accidental absence of suitable alternatives. The only exception to this rule is one of climate, for chloroform is not a very volatile liquid, and in tropical countries the dangers of too great a concentration of chloroform are reduced and its clinical results as regards immediate danger are much better than in temperate climates. Ether is too volatile for use in tropical countries.

(*a*) *Dangers of chloroform*

Chloroform vapour has great anaesthetic potency, and a concentration of 2 to 3 per cent will secure induction, while 1 to 2 per cent suffices for maintenance. The principal dangers of the drug are:

(i) irritant effects on the vagus nerves;

(ii) toxic action on the heart muscle;

(iii) toxic action on the body tissues and parenchymatous glands.

Clinical dangers

Although the precise pathology of some of the effects of chloroform is not universally accepted, the clinical dangers are generally recognized and may be divided under five headings as follows:

(i) *Primary cardiac syncope.*—This may be due either to vagus inhibition or to ventricular fibrillation.

This disaster occurs most commonly during induction of anaesthesia and is dramatic in its suddenness. The patient becomes very pale, and respiration and circulation cease synchronously. Resuscitatory measures must be instituted promptly, but are not usually successful.

(ii) *True overdose.*—This is always due to lack of observation or experience on the part of the anaesthetist, as ample warnings of the descent of anaesthesia through the third into the fourth stage are available if watch is kept on the ocular, respiratory and muscle signs of anaesthesia.

With complete respiratory failure in overdose, the heart's action also ceases, and although resuscitation should always be tried its chances of success are poor.

Relative overdose

(iii) *Relative overdose.*—This may come about in one of two ways, as follows:

(1) Chloroform has a toxic effect on the heart muscle, but some subjects are more sensitive than others. A patient may be in the correct stage of anaesthesia and all seem to be going well, when a gradual deterioration of the circulatory and respiratory system begins. Colour becomes pale, then ashen grey, pulse becomes feeble and respiration increasingly shallow. This means that the heart muscle has suffered a relative overdose and will fail unless the toxic chloroform is immediately removed.

Antidotes

An observant anaesthetist will see the onset of these symptoms and, knowing that this is not a case of true overdose, will at once lower the patient's head, remove the chloroform, and give oxygen plus carbon dioxide (7 per cent). An intravenous injection of Coramine may also be given.

Prompt recognition and treatment of this condition will usually result in recovery. If the operation is to continue, it is advisable to use other agents such as ether, nitrous oxide and oxygen, or Trilene, separately or in combination.

(2) A sudden painful afferent impulse, even though the patient is surgically anaesthetic, may result in the entry of such an additional volume of chloroform by deeper or quicker respiration as to cause a relative overdose on a heart muscle which had until then successfully withstood the toxic effects of the drug.

Prompt treatment will again usually effect recovery, and the anaesthetist should always observe the patient very carefully during periods of painful stimulation with deeper breathing.

(iv) *Delayed chloroform poisoning*.—Acute yellow atrophy of the liver and fatty degeneration of the other organs are found *post mortem* in fatal cases. Even small doses of chloroform have been known to cause this disaster, but it usually follows prolonged administration in a case where sepsis, partial starvation and depletion of the body fluids are present. Drastic purgation and starvation before chloroform administration are a common cause of post-operative ketosis.

Symptoms and signs

As knowledge concerning the proper preparation of any patient before operation is now widely spread, this condition is rarely seen. It is easy to diagnose, the principal symptoms being as follows:

(1) Persistent post-operative vomiting recurring after forty-eight hours.

(2) Persistent occipital headache.

(3) Scanty flow of urine, which contains albumin and the products of ketosis.

(4) Jaundice and painful enlargement of the liver.

(5) Increasing mental confusion and lethargy, which develop into apathy and fatal coma.

Treatment

If the condition is recognized within the first twelve hours, prompt treatment with insulin, fluids and glucose may bring about recovery; but if it is allowed to become established, the prognosis is hopeless.

Fatal ventricular fibrillation

(v) *Fatal ventricular fibrillation*.—On no account should adrenaline be used during chloroform narcosis, as this may cause fatal ventricular fibrillation.

Methods of administration

(*b*) *Methods of administration*

Recognizing the fact that dilute vapour is all-important, anaesthetists have devised a number of machines to secure this end; but although admirable in theory, they

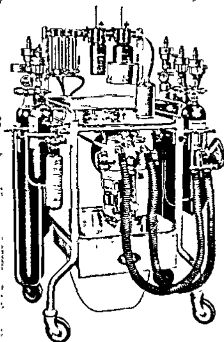


FIG. 75.—Boyle's apparatus for use with $N_2O + O_2 + CO_2$ + ether, Trilene, chloroform or cyclopropane. (*A. Charles King, Ltd.*)

have been found to have little practical value and are seldom used. In these days chloroform is usually administered in one of three ways.

Boyle's machine

(i) *In a Boyle's machine* (Fig. 75) combined with nitrous oxide, oxygen and ether when no fire risk is present. This is probably the best method, because minimal amounts of the drug are used and the dangerous induction period is missed altogether.

Open method with mask

(ii) *By the open method* of dropping chloroform on to a Schimmelbusch mask covered by a single layer of flannel. No additional covering is allowed, as this will cause a dangerous concentration of vapour.

The rate of administration should be neither too slow nor too quick, but as follows:

(1) During the first half minute, one drop of chloroform in each three seconds (10 drops).

(2) In the second half minute, one drop in each two seconds (15 drops).

(3) Maintenance is secured by continuing one drop each two seconds.

As soon as the onset of the second plane of the third stage is recognized, the anaesthetist must realize that the extent of the useful and safe scope of this drug has been reached. If deeper anaesthesia is desired, a change over to open ether should be made.

Switch to ether

Junker's bottle

(iii) *Junker's bottle*. This simple contrivance will deliver a vapour of roughly 2 per cent and is a useful method of providing maintenance anaesthesia.

Precautions

To avoid the dismal effects of wrongful coupling, modern types of Junker's bottle are provided with a safety device. If such device is not present, it behoves the administrator to be meticulously careful that the bellows or oxygen tube are *not* connected to the exit tube, lest fluid and not a vapour be presented to the patient.

(c) *Disadvantages*

In conclusion it is well to draw attention to two other dangers of chloroform.

Chloroform mistaken for ether

(i) Disasters have occurred through mistaking chloroform for ether, as both are colourless fluids. Recognizing this possibility, some manufacturers have coloured chloroform a red colour, and this we consider to be an excellent practice.

Chloroform burns

(ii) Chloroform burns the skin and may cause a blister. Its effects on the delicate membranes of the eye may be serious. Thus scrupulous care must be exercised to prevent chloroform fluid from dropping on to the skin or into the eyes of the patient.

(2) Ethyl chloride

This drug, having the formula C_2H_5Cl (synonyms: chloryl anaesthetic, Kelene), is a colourless volatile liquid, with a slightly sweet but disagreeable odour, a specific gravity of 0·9214 and the low boiling-point of 12·15° C.

Inflammability

The vapour is inflammable and burns with a greenish flame. In recent years the manufacturers have produced samples of ethyl chloride containing few impurities, and have disguised its unpleasant odour by the addition of 1 to 2 per cent of Eau-de-Cologne.

Disadvantages

Ethyl chloride produces anaesthesia quickly and efficiently, but it has the following disadvantages:

(a) It is an irritant to the respiratory tract.

(b) It has cardiac effects of a similar nature to those of chloroform.

(c) In inexperienced hands it may produce symptoms of overdose owing to the speed of its action.

(d) Post-anaesthetic nausea and vomiting frequently occur.

(i) *Indications for use.*—In the days of open ether it was extensively used as an inducing agent, but has now been largely replaced by the basal narcotics such as Pentothal Sodium and Avertin.

As a method of single-dose anaesthesia it secures a brief but efficient narcosis lasting from a minute to a minute and a half, and suffices for minor operations such as the removal of adenoids, the extraction of teeth, the opening of an abscess, or the suture of a trivial wound.

It will often afford sufficient muscular relaxation for the reduction of a dislocation or the immediate reposition of a simple fracture.

Divinyl ether (Vinesthene) is as efficient for single-dose administration and has none of the disadvantages enumerated above.

(ii) *Method of administration.*—Although ingenious types of apparatus have been invented for continuous anaesthesia, these have not been successful, and are seldom used. Ethyl chloride is best administered by the open method. The first plane of the third stage is reached with rapidity. During the second plane the administration should be discontinued whilst: (1) the respirations are still vigorous and show no signs of failure; (2) the pupils, though large, still react to light; (3) the colour is pink and no trace of pallor is seen.

Ethyl chloride may also be used in Goldman's Vinesthene inhaler (Fig. 76), an apparatus consisting of a well-fitting facepiece attached by a wide-bore channel to a three-gallon indiarubber gas bag, into which ethyl chloride in known dose may be poured. Administration may be divided into three stages, as follows:

(1) The bag is half distended with the patient's expired air.

(2) The ethyl chloride is added through a valved tube into the distal or proximal end of the bag.

(3) Air is admitted if: (a) there is any cyanosis; (b) the vapour causes coughing or spasm.

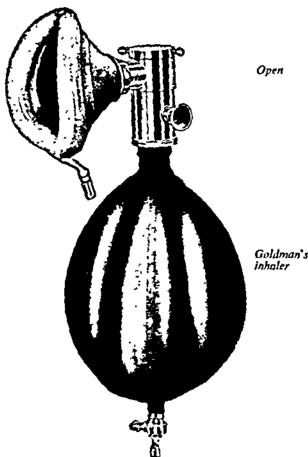


FIG. 76.—Goldman's Vinesthene inhaler. (*A. Charles King, Ltd.*)

Consciousness is lost quickly, and full anaesthesia is often present in from sixteen to eighteen respirations.

Recovery is more prompt than with the open method and there are often fewer after-effects; but experience has shown that the open method is safer, and in our opinion it is to be preferred.

(iii) *Contra-indications.*—Ethyl chloride is not well tolerated in heart disease, acute or chronic pulmonary lesions, renal affections or any gross obstruction of the airways.

On account of the spasm-producing qualities of the anaesthetic, such complaints as whooping-cough, tetany and diseases of calcium deficiency would also render it unsuitable.

(iv) *Conclusions.*—Ethyl chloride should be avoided if better alternative drugs are available.

The two dangers are overdose and high concentration of vapour, both of which can be easily avoided.

The best results are attained by slow induction and by discontinuance of the administration at a time when the patient's colour is good, and he is still breathing vigorously.

(3) Ether (diethyl ether)

Inflammability

Ether is a colourless volatile liquid with a pungent odour. It has a specific gravity of 0·720 at 15·5° C. and a boiling-point of 35·6° C. It is inflammable, and must not be used in the presence of a flame or cautery; furthermore, all apparatus containing this anaesthetic should be earthed by a chain in order to eliminate the risks due to static electrical charges.

Ether tends to decompose during storage, with the production of peroxides and aldehydes, and as these may be a possible cause of the condition known as "late ether convulsions", it is important to insist upon routine testing of samples of ether stored in bulk in hospitals and institutions.

Modern ether products are more uniformly pure than hitherto, since they are treated with carbon dioxide before bottling and have hydroquinone (1 in 1,000 parts of ether) added to delay or prevent oxidation. Copper is a useful and efficient anti-catalyst, and the delivery tube in the ether bottle of anaesthetic apparatus should be made of this metal.

(*a*) *Indications*

One hundred years have elapsed since the introduction of ether, and no anaesthetic agent has been more extensively used. Its advantages and disadvantages are well known, and it is only in recent years that the supremacy of ether as the principal agent for maintenance anaesthesia has been challenged by the introduction of alternatives.

Virtues of ether

Ether has two great virtues—safety and efficiency. The safety of ether depends upon a number of factors:

(a) During induction and light anaesthesia, it is a stimulant and slightly raises the blood-pressure.

(b) Surgical anaesthesia is gradually produced and no sudden or dangerous deepening of narcosis is usual.

(c) In overdose the respiration gradually fails. When it has ceased, the heart continues to function, and if the ether is removed and an adequate airway maintained, the carbon dioxide will increase in the blood and the patient start to breathe again. Should this not occur, it is a simple measure to start artificial respiration. Ether is chiefly excreted by the lungs, and artificial

respiration will supply the patient with oxygen, excrete the overdose and restore the activity of the respiratory centre.

Such a state of affairs usually occurs only in the hands of an inexperienced administrator, but many anaesthetics still have to be given by the "occasional anaesthetist" and the safety of this agent is an indication for its use when the services of a specialist anaesthetist are not available.

(b) Contra-indications

These are as follows:

(i) in respiratory affections;
(ii) in the presence of a cautery or flame;
(iii) in acute nephritis;
(iv) in diabetes mellitus;
(v) in severe shock.

(c) Late ether convulsions

Late ether convulsions

Although the cause of this condition is unknown, the following are contributory factors:

(i) Pyrexia, sepsis and over-heated operating theatres.
(ii) Anoxia in combination with deep anaesthesia.
(iii) Diminution of the physiologically active fraction of the blood-calcium.
(iv) Impurities in the ether.

Treatment.—Raise the head and shoulders, remove the ether supply, give carbon dioxide 7 per cent and oxygen 93 per cent, and slowly inject an intravenous barbiturate until the convulsions cease.

(d) Present-day use of ether

Present use of ether

Specialist anaesthetists recognize the value of this agent, but in view of its sequelae, use it as sparingly as possible. Its true role at the present time is as an adjuvant to mixtures of nitrous oxide, oxygen and cyclopropane. But in the hands of the occasional anaesthetist ether remains a safe and efficient agent for the production of maintenance anaesthesia.

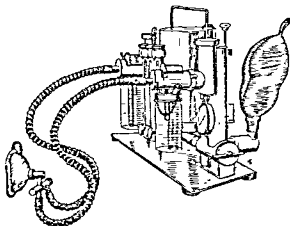


FIG. 77.—Cyclopropane apparatus (Gillies). *(A. Charles King, Ltd.)*

Inflammability

(4) Cyclopropane (trimethylene)

Although first prepared in 1882, this gas has been used extensively only during the last fifteen years. Cyclopropane is a colourless gas with a slight odour. It is heavier than air and is inflammable. The gas is liquefied by the low pressure of 75 pounds per square inch, and as 1 ounce of liquid gas yields 4·29 gallons, it is possible to use small cylinders without reducing valves. Cyclopropane is generally used in a closed-circuit apparatus (Fig. 77) with a soda-lime absorber, the average consumption being 2 gallons per case costing about two shillings.

(i) *Properties of cyclopropane.*—Cyclopropane is a non-irritating gas, is potent even in great dilution, and usually produces good muscular relaxation. It is a respiratory depressant, and in deep anaesthesia may safely be given by expert anaesthetists to produce controlled respiration, for after respiration ceases the circulation will continue unembarrassed if artificial respiration is produced by rhythmic pressure on the gas-bag, provided a clear airway is present. This is secured by intubation with a tube of sufficient calibre.

Respiratory depressant

Cardiac effects

Cyclopropane has cardiac effects, and these are chiefly the production of extrasystoles. It has been observed that an intermittent heart-beat is not usually associated with any deterioration in the patient's general condition, and that this often ceases if more oxygen is added to the mixture, or if a slightly deeper or lighter plane of anaesthesia is effected. The previous injection of atropine and Pentothal Sodium is also of undoubted value as a prophylactic measure against the occurrence of cardiac irregularity.

Premedication

The gas has little effect on the blood-sugar or urea concentration, and is not usually associated with post-operative nausea or vomiting. Post-operative pulmonary complications are uncommon. Patients quickly recover from the effects of cyclopropane, and its freedom from toxicity would seem to aid convalescence.

Indications

(ii) *Indications.*—Cyclopropane is the anaesthetic of choice in the following instances:

(1) For thoracic surgery and for patients suffering from respiratory disease.

(2) In toxic states such as eclampsia, and in acute or chronic septic conditions.

(3) In complete thyroidectomy for congestive heart failure.

(4) Where cardiac compensation is scarcely adequate; here the abundant percentage of oxygen given with the cyclopropane makes this method a safe and valuable one.

For routine anaesthesia

For routine anaesthesia cyclopropane has an increasing vogue both in Great Britain and in the United States of America. Contemporary practice for the majority of operations is to give Pentothal Sodium after suitable premedication, and then to administer cyclopropane in a closed-circuit apparatus. The gas may also be used with ether or divinyl ether, and many anaesthetists prefer to secure deep anaesthesia by this means rather than pushing cyclopropane to the stage of controlled respiration.

Adjuvant to nitrous oxide and oxygen

Cyclopropane may also be used as an adjuvant to nitrous oxide and oxygen. Because cyclopropane and oxygen are quickly absorbed into the bloodstream, the absence of nitrogen or other supporting gas may cause pulmonary complications such as massive collapse. Recognizing this, most administrators use helium or air in the closed circuit. Air may be easily admitted by means of hand bellows attached to the apparatus, and should be given in increasing amounts as the operation nears its conclusion.

(iii) *Disadvantages.*—(1) Complicated and expensive apparatus is required. (2) The risk of using cyclopropane in the presence of a flame or cautery is a serious one, and Hewer (1944a) reports that no fewer than seventy-four cyclopropane explosions occurred in the United States in 1939, with thirteen fatalities. (3) It is suitable for use only by specialist anaesthetists. (4) Muscular relaxation is sometimes inadequate.

Method of use.—A closed-circuit apparatus is essential, and a type in common use is illustrated (Fig. 77).

(5) Trichlorethylene

This anaesthetic, although first described in 1864, has been used extensively in Great Britain only since 1942 following an investigation by the Medical Research Council.

Trilene

The preparation commonly used is known as Trilene and consists of trichlorethylene to which has been added 0·01 per cent of thymol to retard decomposition and 1 in 200,000 parts of "waxoline blue" which gives Trilene its characteristic dark blue colour. The liquid has a characteristic odour which is not pungent, and in dilution can be easily inhaled.

(i) *Properties.*—Boiling-point is 87° C. and specific gravity 1·47. The liquid is not very volatile and cannot be used with efficiency on an open mask.

Non-inflammability

Trichlorethylene is non-inflammable and does not form explosive mixtures with air. If given with oxygen and exposed to the cautery, it will generate negligible quantities of phosgene, and if exposed to heat of upwards of 419° C. it may ignite; but for most practical purposes in surgery this anaesthetic may be said to be non-inflammable. The vapour is non-irritant and may be used with advantage in pulmonary tuberculosis and other diseases of the respiratory system.

Non-irritancy

The blood-sugar and blood-urea concentration are but little affected, and post-operative nausea and vomiting are not usual and are seldom of a severe character.

(ii) *Clinical characteristics.*—Analgesia and a light surgical anaesthesia are easily obtained. Muscular relaxation is, however, usually lacking but can be readily secured by adding adjuvants such as ether or divinyl ether, or by giving a regional nerve block.

Breathing

Rapid shallow breathing sometimes occurs and is usually relieved by increasing the oxygen supply and reducing the strength of the vapour. If this is not successful, it is best to change over to another anaesthetic agent.

Pulse

There may be irregularity of the pulse, but generally without any serious effect. The likelihood of this occurrence is diminished by the previous use of an intravenous barbiturate.

Quantity

Once under the effect of Trilene, the patient needs only a dilute and small supply, and even this may be omitted for a few minutes from time to time. Too much of the drug is commonly given, resulting in delayed return to consciousness.

Unsuitable for closed-circuit apparatus

On no account should this agent be used in a closed-circuit apparatus, as it tends to decompose if brought into contact with soda-lime, with the formation of dichloracetylene and the possible causation of cranial-nerve palsies.

(iii) *Surgical uses.*—Trilene has been used during the last two or three years and is recognized as a useful addition to the choice of anaesthetic agents. It has largely displaced chloroform for use in cases where the diathermy or other cautery is used.

In the chloroform bottle of the Boyle machine it is used with nitrous oxide and oxygen both for induction and maintenance anaesthesia. If greater muscular relaxation is required, the addition of a little ether will secure this, after which the administration can be continued with a little Trilene and gas and oxygen.

Favourable results

Clinically this practice has shown two favourable results: (1) removal of the dangers of chloroform from routine administration; (2) reduction of the quantity of ether used, with a resulting diminution of post-operative sequelae such as nausea, vomiting and pulmonary complications.

(6) Divinyl ether (Vinesthene)

Vinesthene

This is usually used in the form of Vinesthene, which is a mixture of divinyl ether with 3·5 per cent absolute alcohol and 0·01 per cent phenyl-α-naphthylamine, the liquid being bottled in an atmosphere of nitrogen.

Inflammability

Toxic effects

Overdose

(i) *Properties.*—A colourless volatile fluid with a specific gravity of 0·77 and the low boiling-point of 28° C. It is inflammable and forms an explosive mixture with air or oxygen. Vinesthene must be used as soon as possible after exposure to the atmosphere, as this causes decomposition and a loss of potency. Its toxic effects on the body are similar to those of ether, but the blood-sugar is less disturbed and the liver function is less impaired. In overdose, with failure of respiration, the circulation continues, which is a safety factor of importance. Convulsions of a type similar to those of ether have been recorded and are treated in the same way as late ether convulsions.

Advantages

Clinical uses.—Speed of action, production of good muscular relaxation, freedom from irritant effects on the respiratory tract, and from post-operative nausea and vomiting, make this agent valuable. It may be used as a single-dose agent to produce a surgical anaesthesia lasting from one to two minutes. The vapour has little odour, and this may be disguised by the addition of a trace of oil of lavender on the mask or face-piece.

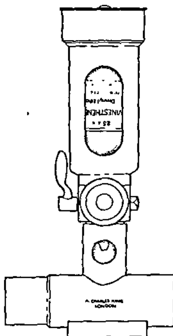


FIG. 78.—Goldman's Vinesthene dropper. (*A. Charles King, Ltd.*)

Children take and tolerate this anaesthetic well, and it is useful for the extraction of temporary teeth and for the removal of adenoids.

Mode of use

Although Vinesthene can be used on the open mask, this is an inefficient and wasteful method, and better results accrue from the use of a Goldman inhaler and its various modifications (*see* Fig. 76).

As a continuous agent it makes an excellent adjuvant to nitrous oxide and oxygen, and is best used in a closed-circuit with soda-lime carbon dioxide absorber. Goldman's dropper, which may be included in the circuit of any apparatus, enables Vinesthene to be added efficiently and in known dosage (Fig. 78).

(7) Nitrous oxide (N_2O)

Nitrous oxide

Nitrous oxide is an almost odourless and non-irritating gas which is inhaled with ease and produces anaesthesia with speed and efficiency.

Properties

(*a*) *Properties*

Nitrous oxide is heavier than air, and modern samples are remarkably free from impurities. Pure nitrous oxide does not actively support

combustion, but will do so if it is contained in a mixture with oxygen. When first inhaled, nitrous oxide slightly stimulates respiration and raises blood-pressure.

This agent has little effect on the parenchymatous glands or on the urea and sugar concentrations in the blood, and provided anoxaemia be avoided it is the safest and least harmful to the body of all the general anaesthetics. Post-operative nausea, vomiting and pulmonary complications are usually absent.

Safety.—With regard to safety, Hewer (1944b) reports that as the result of a *questionnaire* circularized in America, a total of 1,161,820 administrations for dental operations revealed only two fatalities—a mortality rate of 0·00017 per cent.

At Guy's Hospital 1,271,431 administrations have been recorded without any fatality (Marston, 1945).

(*b*) *Surgical use*

Uses

Nitrous oxide may be used as follows:

(i) *As a single-dose anaesthetic.*—For simple procedures in minor surgery, N_2O produces surgical anaesthesia quickly and efficiently, and lasts from forty-five seconds to one minute.

Primary saturation

(ii) *As a continuous anaesthetic.*—When the first plane of the third stage of anaesthesia is reached, the oxygen in the circulating blood has been replaced by nitrous oxide and this is known as *primary saturation.*

If continuous anaesthesia is desired, it is necessary to add enough oxygen to supply the minimal demands of basal metabolism, otherwise any further administration of N_2O produces effects due to a graduated asphyxia.

Secondary saturation

In America the practice of continuing administration of pure N_2O until *all* the oxygen in the body has been replaced is known as *secondary saturation.*

If oxygen is then added under pressure, the patient attains muscular relaxation, and the administration of N_2O proceeds with sufficient oxygen.

After an extended trial in Great Britain, this method has been abandoned on account of its depressing effects on the body.

It is accepted that continuous administration of N_2O and oxygen for surgical procedures of any length is possible only when the drug is used with the following adjuncts.

(1) *Premedication or basal narcosis.*

(2) Graduated positive pressure—best employed with an intermittent flow.

(3) Sub-oxygenation.

(4) The addition of volatile adjuvants, such as ether, Vinesthene, chloroform or cyclopropane.

Sub-oxygenation is to be deprecated on account of its pathological effects, and should not be used.

Minnitt's apparatus

(iii) *As an analgesic.*—Nitrous oxide when mixed with air forms an excellent analgesic. Minnitt's apparatus (Fig. 79) is the most reliable of the several available for this work, and by intermittent flow delivers a mixture of 45 per cent N_2O and 55 per cent of air, which provides efficient analgesia and enough oxygen (11 per cent) to support metabolism. This apparatus is useful for surgical dressings of a painful nature. The patient is instructed to breathe regularly into the facepiece of the apparatus for two to three minutes *before* the dressing is started, and then continues to use the apparatus until the dressing is completed. There is an entire absence of post-analgesic

For painful dressings

sequelae, and once the patient's confidence has been gained, it forms an admirable method for work of this nature.

Premedication with morphine or barbituric acid derivatives increases the scope of analgesia in resistant patients.

(iv) *Indications for continuous nitrous oxide.*—The use of nitrous oxide forms the basis of most modern routine techniques of inhalation anaesthesia. Modern apparatus of the well-known Boyle type has been developed to provide both semi-closed and closed anaesthesia, and nitrous oxide with oxygen is administered with cyclopropane and volatile adjuvants, such as ether, Vinesthene, Trilene and chloroform, always remembering that *Trilene* must *not* be used in the closed circuit (*see* Fig. 75).

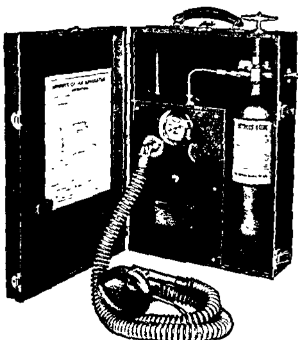


FIG. 79.—Minnitt's gas-and-air analgesia apparatus. (*A. Charles King, Ltd.*)

In practice, if adequate premedication and basal narcosis are secured, a minimum of adjuvant drugs is used; and as nitrous oxide produces little damage to the body, the after-results from the routine use of such apparatus, always provided no shortage of oxygen be permitted, is a great improvement on previous types of routine administration such as ether by the open or closed Clover methods.

(*c*) *Methods of administration*

Two types of modern apparatus now most popular in general use are illustrated (*see* Figs. 75 and 77).

Closed-circuit apparatus

(i) *Closed-circuit apparatus.*—Volatile narcotics and anaesthetic gases are excreted by the respiratory system unchanged as regards their anaesthetic potency, but having a carbon dioxide content of about 4 per cent. If the carbon dioxide is removed by passage through a soda-lime canister, and enough oxygen is added to supply adequately the metabolic needs of the body, then anaesthetic vapours and gases may be used over and over again. This practice has the following advantages:

(1) Economy.

(2) Conservation of water vapour.

(3) As the passage of expired air through soda-lime generates heat, the gases in the closed circuit are warmed to approximately body heat.

(4) Respiration has a tranquil rhythm unattained by other methods of anaesthesia, and it is possible to practise "controlled respiration" when required.

Absorbers

(ii) *Types of carbon dioxide absorbers.*—The original "to-and-fro" breathing

canister introduced by Waters is now seldom used. Although efficient in action, it is difficult to hold and to adjust during administrations of any length. Its place has been taken by the "circle" or "two-phase system" in which the canister is placed so that expirations pass through the absorber and are reinhaled. This is made possible by using separate tubes for inhalation and expiration, and keeping their contents separate by means of one-way valves.

The "circle" type of rebreather, though not so perfect as the original "to-and fro", gives excellent results in practice.

(iii) *Soda-lime*.—A number of products are available. It is advisable to choose a soda-lime which is "non-hygroscopic", and free from dust, and in which the granules are of a size between 4 and 6 mesh.

Soda-lime

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[References to other titles are given under Anaesthesia in the Index Volume. The subject of Anaesthesia is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 472.]

ANAESTHESIA—LOCAL

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1. DEFINITION AND PRINCIPLES

27.] The expression "local anaesthesia" is here used to mean paralysis of sensory nerve fibrils and terminals induced by injecting an anaesthetic agent in and round the field of operation, so that the structures concerned can be divided and separated painlessly. The locally acting anaesthetic agent is usually combined with a sedative to allay apprehensiveness, but the ideal at which local anaesthesia aims is fundamentally different from that of general anaesthesia. With the latter the whole is necessarily anaesthetized to the depth required for an operation on the part; the objective of local anaesthesia is to avoid all general disturbance. The patient may be somnolent, but he remains in control of his vital functions and is easily roused. Since only the tissues in, and immediately round, the field of operation need be anaesthetized, infiltration is usually done most precisely by the surgeon himself.

2. AGENTS

A wide variety of *British Pharmacopoeia* derivatives of cocaine and trade preparations for local analgesia is available; the following are most commonly used: procaine hydrochloride (synonym: Novocain, Planocaine), ½ to

2 per cent; amethocaine hydrochloride (Decicain, Anethaine, Pontocaine Hydrochloride), 1 : 3,000; Nupercaine (Percaine, Sovkain), 1 : 3,000.

For minor operations 1 per cent procaine may be used, but for more extensive procedures necessitating larger quantities of solution the tendency now is to employ an agent acting in higher dilution and involving less risk of toxic effects; Decicain and Nupercaine in the dilutions indicated give complete analgesia. They have the added advantage over procaine of producing a more enduring effect. Decicain, being more stable, is preferable to Nupercaine.

Massive local infiltration

Sufficient solution should be injected to soak the operation field. Very large quantities of 1 : 3,000 Decicain (more than one litre) may be injected harmlessly, so that overdosage with this agent does not appear to be a material risk. The technique of using very large quantities of dilute anaesthetic agent is known as massive local infiltration. Adrenaline fortifies the action of local analgesics and should be added to a strength of 1 : 250,000 to 1 : 500,000. The subcutaneous injection of normal saline or of normal saline and adrenaline 1: 500,000, does not produce analgesia in the overlying skin. Ordinary tap water is said to have this effect, but the use of such hypotonic fluids is clearly objectionable.

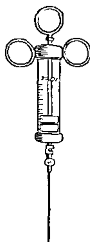


Fig. 80.—Labat type syringe.

Preparation of solutions

All local anaesthetic agents should in fact be freshly prepared in normal saline and solutions should be sterile. Neglect of these precautions may result in tissue damage, wound sepsis and delayed healing. Solutions of Nupercaine 1:3,000, Decicain 1:3,000 and adrenaline 1:250,000 are almost neutral and do not inactivate penicillin; procaine (including Novutox) and cocaine, which are distinctly acid, do, and are therefore better avoided when penicillin insufflation is necessary (Rundle, 1945).

Penicillin inactivation

3. APPARATUS

The choice lies between three kinds of apparatus, as follows.

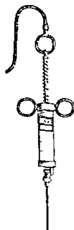


Fig. 81.—Rowbotham's continuous-flow syringe.

(1) Syringe of Labat type

This syringe is fitted with needle-lock and finger grips (*see* Fig. 80). This is simple and satisfactory for ordinary purposes.

(2) Continuous-flow syringe

This may be of the Vann (British) or Dunn (American) type. Withdrawal of the plunger automatically refills the barrel through a non-return valve in the side tube attached near the nozzle. This side tube is flexible and has a sinker which keeps the end submerged in the anaesthetic solution. For long infiltrations the continuous-flow syringe saves time. Another type of continuous-flow syringe is shown in Fig. 81.

(3) Pressure infiltrator

Of the various machines to facilitate local infiltration, James's seems most simple and efficient, and constitutes a technical advance of interest (James, 1944). With it, the

tissues are infiltrated rapidly and without effort. A reservoir of anaesthetic solution is put under pressure of oxygen or carbon dioxide in an airtight container. The solution is forced along a flexible pipe-line to a pistol-grip, whence the flow is regulated by a trigger control. The pressure infiltrator is designed to lay on anaesthetic solution for surgeons who use it frequently, and to provide a ready substitute for general anaesthesia when the services of a skilled anaesthetist are not available.

The machine is sterilized by blowing steam through and holds enough solution for thirty to forty mixed operations. Being airtight it can be used for successive operation lists until empty, without resterilization. The pipe-line and pistol-grip are boiled before each session, and between operations only the needle need be changed.

4. THE PATIENT'S MENTAL AND PHYSICAL COMFORT

Psychological aspect

Frequent practice and good team-work are necessary for the successful conduct of major operations under local anaesthesia. The ward atmosphere is important. Where many operations are being efficiently done by this method, new patients derive confidence from the appearance and opinion of those already treated. Pre-operative treatment is similar to that for general anaesthesia but more laxity is permitted in diet; a light meal may be taken from one to two hours before operation. Moreover, premedication is of supreme importance and its effectiveness largely conditions the success or failure of the method, especially in nervous subjects. The ideal is to have the patient soundly asleep before leaving the ward, yet not so drugged that the respirations are depressed, the jaw requires support, or somnolence persists after operation. Patients operated on under local anaesthesia suffer little general disturbance and should be capable of sitting up and breathing deeply, reading, and even taking the next meal in comfort. Therein lies the justification of the extra care required by the method. Premedication should be adjusted to individual requirements, but Nembutal, grains 3 one hour before operation, combined with Omnopon, grain $\frac{1}{3}$ and scopolamine, grain $\frac{1}{150}$, half an hour before, is generally effective. After the Omnopon and scopolamine, it is helpful to transfer the patient to the theatre trolley, darken the room, bandage the eyes and plug the ears lightly with cotton-wool.

Premedication

In the theatre too, the atmosphere should be one of quiet assurance, and care must be exercised in choosing remarks. For example, the surgeon should ask: "Are you quite comfortable?" rather than : "Do you feel this?", or "Is that painful?". Mental suggestion is facilitated by the circumstances and should not be unfavourable. The theatre table should be covered with soft Sorbo rubber; pillows are placed behind the head and knees, and the wrists and thighs are supported and loosely secured with soft leather straps passed under the table.

Comfortable posture

5. TISSUES TO BE INFILTRATED

(1) Types of pain

The late Sir Thomas Lewis (1942) distinguished superficial and deep pain. Pain arising in skin is particularly sharp and well localized, and in large

measure the same is true of pain from superficial periosteum, tendon, fascia and joints. But when deep muscles, ligaments, periosteum, joints and mesenteries are stimulated pain tends to be dull and diffuse—a disagreeable sensation not easily described.

(2) Superficial and deep structures

It follows that adequate infiltration of superficial structures is essential. Failure to infiltrate deeper tissues may result in little or no complaint if handling is gentle, but otherwise there may be real discomfort, poorly localized and described often as an intolerable pressure. Such deep pain may cause restlessness and uncontrollable contraction of the local musculature; *mere infiltration of the operation field cannot cause widespread paralysis of* related muscle groups, the motor supply of which is often by distant nerve trunks. The surgeon relies, in fact, on the patient's being co-operative and lying quiet during operation. Granted adequate infiltration and premedication, this reliance is rarely misplaced in normal subjects.

Muscle grou[ps] remain contractile

(3) Sensitivity of different tissues

To minimize difficulties the surgeon should study the natural pain potentialities of the different tissues. These may be indicated briefly. Apart from cutaneous nerves penetrating it, subcutaneous fat gives rise to little pain when incised, but cutting deep fascia is distinctly painful. The pain from clean incision of somatic muscles is slight, but squeezing muscle, as by pressure of retractors, may cause severe pain. The same is true for tendons. Periosteum is very sensitive, but bone may be gouged or sawn across painlessly. The articular surfaces of joints are insensitive, but stimulation of the synovial lining causes severe pain. In clearing main arteries or veins preparatory to ligature, pain is usually caused unless the adventitia has been infiltrated.

As is well known, the skull, dura mater, pia mater and brain surface are generally insensitive to burns and incision. Lung tissue and visceral (but not parietal) pleura may also be incised painlessly. Visceral and even parietal pericardium are painless to scratch, but ligation of, or traction on, arteries of both brain or heart wall causes pain. Parietal peritoneum with its subserous layer is very sensitive. Solid and hollow abdominal viscera yield no pain to direct stimulation, but traction on the hollow viscera, especially of the upper abdomen, causes pain, probably by exciting sensory nerves in the base of mesenteries.

6. TECHNIQUE

(1) Subcutaneous infiltration

It is relevant to describe a simple experiment which the surgeon using local anaesthesia will find it salutary to repeat on himself: 20 cubic centimetres of sterile normal saline containing Decicain 1 : 3,000 and adrenaline 1 : 500,000 are injected subcutaneously through a skin weal in the dorsum of the hand. The injection itself is almost painless and balloons up the skin over practically the whole of the dorsum. Absolute analgesia to pin-prick and pinching with artery forceps comes on almost instantaneously, rapidly

Test

extends practically to the margin of the swelling and persists for some six to seven hours.

Requirements for success

It follows that cutaneous analgesia can be relied on if the solution is injected widely in the subcutaneous plane, and that it is practically coextensive with the swelling produced. For consistent success with local anaesthesia three conditions should be fulfilled. First, subcutaneous infiltration should be wide and thorough. Secondly, the needle should be kept in constant movement. This prevents the intravascular injection of a large quantity of analgesic agent. Small quantities of 1 : 3,000 Decicain thus injected are innocuous and merely pricking a small vessel in the course of infiltration anaesthesia does no harm. Finally, injection of the deeper tissues must not be skimped; in general, this is best done under vision to avoid damage to important structures. Farr (1929), Vishnevskiy (1941) and others advocate "intra-sheath infiltration". By this is meant the injection under pressure of successive anatomical compartments before opening the overlying fascias. Better spread of solution and more efficient analgesia are thus obtained. Infiltration, however, must still be centred on the line of incision; very distant spread cannot be relied on.

Intra-sheath infiltration

(2) Infiltration for inguinal hernia

Technique of local anaesthesia

It is proposed, by way of illustration, to describe the technique of local anaesthesia for the reduction of strangulated inguinal hernia. When the operation field is exposed and prepared, the subcutaneous tissues in a line just above and parallel to Poupart's ligament, and over the swelling, are heavily infiltrated with anaesthetic solution. This is done through a single intracutaneous weal made near the anterior superior iliac spine with a sharp hypodermic needle. Any punctures subsequently necessary should be through skin already anaesthetized from beneath. The area infiltrated extends from the anterior superior spine to the root of the penis, and for two inches above and below the line of the inguinal canal. The latter is now exposed but not opened. A further quantity of solution is injected under pressure just deep to the aponeurosis forming the anterior wall, from a point one inch lateral to the internal ring to the level of the fundus of the hernia or body of pubis, whichever is lower. This injection suffices to anaesthetize the superficial coverings of the sac, which is then exposed and opened. The ilio-inguinal nerve may not be completely blocked, in which case it should be injected directly or retracted. To facilitate clearing the neck of the sac, anaesthetic solution should be injected under pressure between it and the fascia transversalis. This also anaesthetizes the peritoneum round the internal ring. In general, the operation can be completed without further anaesthesia, but sometimes mesentery (during extensive procedures on small intestine), conjoined muscle and tendon and the tissues behind the cord (during Bassini's repair) still require infiltration.

7. THE SURGEON'S TASK

Gentle manipulation

To the surgeon working on a patient under local anaesthesia, normal tissues appear oedematous, and excess fluid escaping into the field of operation necessitates additional swabbing. Local anaesthesia also enforces on the surgeon gentle handling of the tissues, but this is probably an unmixed blessing for the patient. Dissection must be as deliberate and complete as under

general anaesthesia. Pressure infiltration may in fact be used to aid dissection by separating adherent layers. At no time should imperfection of anaesthesia be allowed to dictate the course, or limit the completeness, of operation, and supplementary general anaesthesia should be available in cases where it seems possible that circumstances might arise necessitating its use.

8. THE PATIENT'S REACTION

During infiltration of subcutaneous tissues, slight pain precedes the rapid onset of analgesia; afterwards only a vague sensibility to pressure persists. After adequate infiltration operation can be accomplished painlessly but hyper-apprehensive patients may remain acutely aware of local manipulation. The incidence of such hyper-apprehensiveness is not high (less than 5 per cent) but its recognition is important, for in such patients restlessness may interfere with the well-ordered conduct of the operation. Whenever possible such reaction should be anticipated and met by the administration of just sufficient general anaesthetic (nitrous oxide and oxygen or Pentothal) to maintain light sleep. This does not depart from the principle of local anaesthesia since the generally-acting agent is being used *qua* sedative. The same technique may, with advantage, be used when operation is likely to be prolonged; the mere fact of remaining still during a long operative procedure is likely to prove an ordeal for most patients. The patient's temperament and the efficacy of premedication are of prime importance.

Hyper-apprehensive patients

Supplementary narcosis

9. POST-OPERATIVE PAIN

After Decicain anaesthesia there is generally complete freedom from pain for five to six hours. During this period, the surgeon may be deceived into thinking that no post-operative morphine is necessary. But pain may come on later and be severe; morphine should not be withheld.

10. WOUND HEALING

As has been indicated, the injection of hypotonic or otherwise non-physiological preparations may delay healing, but by observing the simple precautions previously mentioned, this deficiency is avoided. Evidence that local infiltration *per se* is harmless has been provided by the results of delayed suture in patients with multiple war wounds given Pentothal. I selected pairs of similar wounds, one member was infiltrated with solution (1 : 3,000 Decicain and 1 : 500,000 adrenaline in sterile normal saline), the other not. The percentage of successful sutures showed no significant difference in the two groups.

11. SCOPE

When the necessity arises almost any operation *can* be done under local anaesthesia. The method is undoubtedly best in some instances, notably for inserting an intercostal catheter or resecting a rib in empyema, or for strangulated hernia in the patient with prolonged obstruction. But in normal circumstances and for the generality of operations there is a choice of method, and much will depend upon the personal inclination of the patient and surgeon,

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Gentle manipulation

previous infiltration must of necessity be inaccurate. Other agents (nitrous oxide and oxygen or Pentothal) are preferable. The use of local anaesthesia for the treatment of septic fingers is actually dangerous. The tissues may already be tense from inflammatory oedema, and if anaesthetic solution is also forced in, spreading infective gangrene may be precipitated.

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[*References to other titles are given under* Anaesthesia *in the Index Volume.* The subject of Anaesthesia is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 472.]

and the facilities available. Operations take longer under local anaesthesia because the surgeon must proceed gently and infiltrate deep structures. The ability to identify, and work in, oedematous tissues is also necessary, but is soon acquired.

(1) Advantages

The chief advantage of local anaesthesia is that it is supremely safe and causes no major physiological upsets. In careful measurements of blood-pressure and pulse rate before and after extensive infiltrations, I have found the average values to remain substantially unchanged. For this series of measurements, adrenaline 1 : 500,000 was added to the anaesthetic solution; with higher concentrations some pressor effect may be produced. Fainting, with sharp fall of blood-pressure, occasionally occurs with the initial needle prick. The head of the table should be lowered, but recovery is, in any case, spontaneous and rapid.

(2) Minor operations

A wide variety of minor operations, such as excision of superficial swellings and suture of a cut scalp or divided tendon, may be accomplished by the surgeon single-handed. Since a minimum of post-operative supervision is necessary it serves for many operations on out-patients. Some study and practice of the method are, however, required before the surgeon can regularly obtain complete analgesia and carry through major operations without interruption.

(3) "Poor risks"

Where operation becomes necessary in old or enfeebled patients and those suffering from serious general disease, the tendency is to choose local anaesthesia. By avoiding inhalation and recumbency, post-operative chest complications are minimized. In shocked patients, too, the method promises well; more work is required in this field.

(4) In special fields

In the special fields of surgery—cranial, thoracic and plastic—local anaesthesia has important applications. In traumatic surgery, it serves, among other purposes, for the reduction of fractures and for relieving pain and promoting movement of recently strained ligaments.

(5) Inadequacies

In abdominal surgery local infiltration of the line of incision and field of operation alone does not give adequate relaxation. Traction on parietal peritoneum or mesentery appears to affect sensory nerves at a distance, causing widespread contraction of the abdominal wall. Here, regional analgesia, which involves the accurate injection of nerve trunks, usually with stronger solutions and at a distance, is to be preferred.

(6) Contra-indication

Local anaesthesia is not advised for the incision of abscesses. Here the requirements are brief analgesia, a wide incision, disruption of loculi and perhaps exploration of a deep track. The extent of the cavity and direction of the track are determined by digital exploration only during operation. Thus

vision, guaranteeing complete anaesthesia. Paraneural injection is the usual technique, but occasionally the opportunity is offered of injecting the nerve trunk directly, as in injection of the sciatic nerve during a thigh amputation.

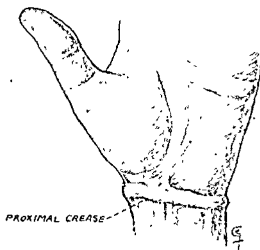


FIG. 83.—Field block.

(2) Field block

This expression has been applied to the technique of building up a wall of anaesthetic solution around, but away from, the operation field with a view to intercepting the nerves running to it (Fig. 83). In practice this method is, however, unreliable, and in the end recourse must be had to infiltration anaesthesia. Therefore no attempt is made here to describe, or perpetuate, the claims made for field block.

3. REQUIREMENTS FOR REGIONAL ANAESTHESIA

(1) Knowledge of surface anatomy of nerve trunks and technique of blocking them

Main blood-vessels usually accompany the nerve trunks, and intravascular injection of the anaesthetic solution must be sedulously avoided. Three applications of regional anaesthesia are commonly used in general surgery, and these alone are described in this article. The same principles govern its use in other sites. A scrupulously aseptic technique should be observed.

Avoid intravascular injection

(2) Apparatus

(a) Syringes

Many special forms of syringe are available for regional anaesthesia, but any smooth-working, 10 cubic centimetre syringe of Record type, whether with central or eccentric nozzle, will serve.

(b) Needles

These should preferably be of stainless steel, and must always be kept in good condition. The following sizes are useful:

(i) small hypodermic needles;

(ii) medium-length needles, 6 to 8 centimetres long but *not more than* 0·8 millimetre in diameter;

(iii) long needles not less than 12 centimetres in length and not more than 1 millimetre in diameter.

Each medium and long needle should have threaded on to it a small piece of rubber to act as a depth recorder when locating bony landmarks.

(3) Drugs

Procaine hydrochloride (Novocain, Planocaine) is still the most used agent, but of recent years amethocaine hydrochloride (Anethaine,

ANAESTHESIA—REGIONAL

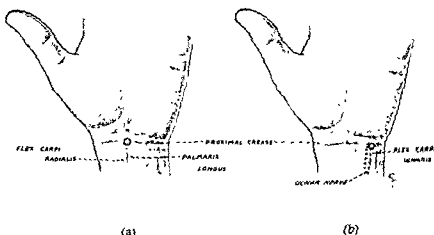
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1. DEFINITION

28.] Regional anaesthesia means that there is loss of sensation, including pain, induced by agents injected into or around nerve trunks at a distance from the field of operation.

2. DIVISIONS

Regional anaesthesia has traditionally been described under two headings: (1) nerve block, and (2) field block.



(a) (b)
Fig. 82.—Nerve block: (a) median nerve, (b) ulnar nerve.

(1) Nerve block

The injection is generally made near the nerve (paraneural *injection*), usually with a strong solution, the anaesthetic agent diffusing into the nerve trunk (Fig. 82). Alternatively, an intraneural injection can be made under

should transmit a pulsation to it. The rubber marker is pushed down to the surface of the skin so as to prevent the needle from going in deeper when searching for paraesthesia. Paraesthesia may be elicited during the insertion of the needle. If not, it is sought by moving it slightly medially, and even laterally, taking care to withdraw it slightly each time its direction is changed. If paraesthesia is elicited there is often twitching of the hand. Immediately paraesthesia is obtained the needle is held firmly and the syringe is attached. A small amount of the solution is injected to clear the lumen of the needle, and the aspiration test is then carefully performed. If this is negative the contents of the syringe are injected, but not before the aspiration test has been repeated at least once. Towards the end of the injection the needle should be slightly withdrawn.

Paraesthesia

Aspiration test

The syringe is refilled and further solution is injected after careful aspiration, even if no more paraesthesia is obtained. Altogether 100 cubic centimetres of the solution is used, and should paraesthesia be altogether absent then the Patrick technique is followed throughout (Patrick, 1940). Using up to 100 cubic centimetres of anaesthetic solution ensures success, because this large amount of solution compensates for any inaccuracy in locating the exact optimal point of injection; indeed some authorities claim uniform success with lesser amounts.

Patrick technique

(2) Thoracic nerve block

This is suitable as an adjuvant for upper-abdominal and mid-abdominal operations.

Position of patient

The patient lies on his side in a similar posture to that for lumbar puncture. After preparing the back with iodine and spirit from the buttocks to the scapula, and from mid-axillary line to mid-axillary line, a fresh swab is soaked in spirit and with this a line about 1 inch wide is marked on each side of the spine, and four-fingers' breadth from it, extending from the level of the scapula to the intercristal line. The 10 cubic centimetre syringe is fully charged with anaesthetic solution, and its nozzle is turned upwards with the barrel clasped in the palm of the right hand, leaving the thumb and forefinger free. One of the medium-sized needles is picked up with the left hand and transferred to the free thumb and forefinger of the right hand, so that the hub is firmly

Technique

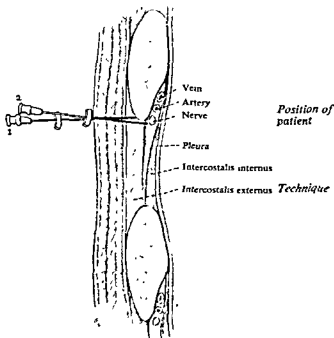


FIG. 84.—Thoracic nerve block.

Decicain, Pontocaine Hydrochloride) has become popular owing to its relative non-toxicity in weak solutions and its intense and prolonged anaesthetic action.

Concentration

It should be noted that greater concentrations of these agents are necessary for regional than for local infiltration anaesthesia. Those recommended are: procaine—1 per cent to 2 per cent; amethocaine—1 in 2,000 to 1 in 1,000.

4. TECHNIQUE

The psychological aspects of treatment and preparation of the patient are the same as for local infiltration anaesthesia, which is dealt with elsewhere.

5. APPLICATIONS IN GENERAL SURGERY

The following are the chief applications of regional anaesthesia in general surgery.

(1) Brachial-plexus block

Position of patient

Technique

The technique of Kulenkampff (1912), slightly modified, is recommended. The patient is placed on a table (a concave surface such as a stretcher trolley must be avoided), and a small sand-bag or pillow is placed longitudinally between his shoulder blades so as to brace the shoulders back. Only a low pillow is provided for the head, which is then turned away from the side to be injected. The anaesthetic solution may be prepared by adding 100 milligrams of amethocaine hydrochloride to 100 cubic centimetres of normal saline to which has been added 0·25 cubic centimetre of 1 in 1,000 adrenaline hydrochloride. The shoulder, side of the neck and infraclavicular region are painted with antiseptic lotion and surrounded with sterile towels. The subclavian artery is palpated with the index finger of the operator's left hand. It lies just above (a) the mid-point of the clavicle as determined by palpating the acromio-clavicular and sterno-clavicular joints, and (b) the point where the continuation of the line of the external jugular vein meets the clavicle. The vein can be made to stand out by asking the patient to blow out the cheeks. When the artery has been located an intradermal weal is raised over the site as a landmark. A 10 cubic centimetre syringe charged with the anaesthetic solution is held in the palm of the right hand, while the thumb and forefinger of this hand hold the hub of a 7 to 8 centimetre needle with a rubber depth marker attached. The point of the needle is gently introduced through the intradermal weal, and manoeuvred backwards, inwards and downwards as follows.

(*a*) *Backwards.* The needle is directed so that it points at right angles to the table.

(*b*) *Inwards.* The hub of the needle is then swung outwards through an angle of 45°.

(*c*) *Downwards.* The hub of the needle is now made to traverse one-quarter of a right angle upwards.

Final position of needle

Thus the point is directed 45° inwards and about 22° downwards. The final position of the needle is such that if its line were continued it would meet the body of the second thoracic vertebra. When the needle finally points in this direction it is pushed gently in until its point touches the superior surface of the first rib. This it does in close proximity to the subclavian artery, which

tenth and eleventh intercostal spaces are appreciably wider than the higher ones.

(3) Anterior splanchnic block

Technique

Through a midline incision the lower border of the liver is carefully retracted. The anterior surface of the first lumbar vertebra is searched for with the middle finger of the left hand, the aorta being gently displaced to the left,

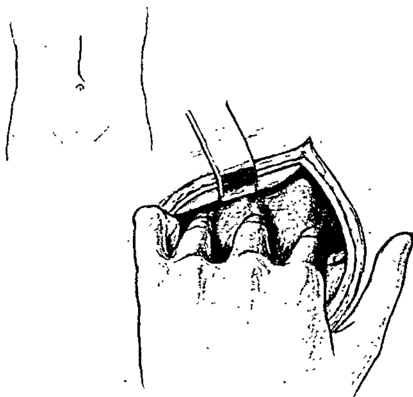


FIG. 85.—Anterior splanchnic block.

and, if necessary, the vena cava to the right (Fig. 85). The tip of the finger then comes into contact with the middle of the anterior surface of the vertebra, being separated from it only by the attachment of the crus of the diaphragm. An ordinary 12-centimetre needle or a special splanchnic block needle, such as Kindersley's modification of Finsterer's, is then guided past the finger-tip and pushed down to the bone (Fig. 86). Its point strikes the bone almost immediately after entering the soft parts. Should the aspiration test be negative the finger is withdrawn and, without moving the needle, 100 cubic centimetres of the anaesthetic solution is injected. This produces extensive infiltration of the soft parts, covering the anterior and lateral surfaces of the vertebra.

Aspiration test

held. The twelfth rib of the right (upper) side is now palpated with the index or middle finger of the left hand. At *a point on its lower border, four-fingers' breadth from the midline* (just outside the lateral border of the erector spinae, and on the line marked with spirit), the needle point is inserted *vertically to the skin with a quick stabbing motion. An intradermal weal is* unnecessary if the needle point is sharp and the skin is pierced quickly. The point of the needle is gently advanced until it strikes the lower border of the *twelfth rib. The rubber marker is then set at 1 centimetre* from the surface of the skin and, by slightly altering the angle of the needle, the point, when advanced, slides off the lower border of the rib. The point is then advanced to a depth not more than 1 centimetre beyond the lower border of the rib (Fig. 84). The syringe is now attached by means of a firm twisting motion, and the point is withdrawn to the lower border of the rib and again advanced. This is repeated several times, and during this to-and-fro movement the whole contents of the syringe are discharged at an even rate. The aspiration test is unnecessary as, during the whole time that the analgesic solution is being injected, the point of the needle is kept moving backwards and forwards in a plane at right angles to the subcostal artery and vein.

Aspiration test unnecessary

The operator soon learns to appreciate the sensation given when the point of the needle penetrates the muscular layers connecting adjacent ribs. As it is impossible to determine precisely in which layer the needle point is lying, he must rely on the *to-and-fro motion to distribute the injection* amongst all the layers. Thus sufficient solution will be deposited in the tissues round the intercostal nerve. In practice this technique always achieves full anaesthesia. *Should the needle be advanced more than 1 centimetre from the* border of the rib, pleural or even pulmonary puncture may occur. This undesirable effect is generally indicated by the patient's coughing. No harm results if asepsis is complete.

Distribution of injection

Once the injection has been completed the syringe is detached from the needle by a twisting motion. The needle is left *in situ* so as not to "lose one's place". The syringe is recharged and then, *holding it as before in the right* hand, the lower edge of the next rib (eleventh) is palpated with the middle or index finger of the left hand. Once the edge is felt the finger is kept in position to mark it. *With the right hand still holding the syringe, the hub of the* embedded needle is seized by the thumb and forefinger, pulled out, and re-inserted at the new level marked by the palpating finger. The syringe is again attached with a firm twisting motion and its contents injected as *before.*

The seven thoracic nerves (Th. 12 to Th. 6 inclusive) are blocked in this manner, and then without altering the position of the patient the procedure is repeated on the lower (left) side, making fourteen *injections in all.*

No difficulty should be experienced in injecting Th. 7 and Th. 6 in the same longitudinal (spirit-marked) line as the others, providing the space between the medial borders of the scapulas is widened *by crossing the patient's arms.* Should it be necessary to approach nearer the spine, care should always be taken to see that the point of the needle is directed outwards and not inwards. Thus any chance of an intrathecal injection is avoided. *In very obese patients* it may not be possible to palpate the ribs, in which case the position of each is judged approximately, and the rib margin actually found by gentle exploration with the needle-tip. *This is not difficult, but it should be noted* that the

Direction of needle

aspiration test is negative, as it signifies that the point of the needle lies correctly in the loose retroperitoneal tissue, previously described.

If a definite resistance is offered to pressure on the piston, this usually means that the point of the needle lies in the crus of the diaphragm. This is often due to placing the intradermal weal (point of entry of the needle) too far out from the midline, so that when the needle is introduced its point tends to slide along the front of the body of the vertebra instead of past its anterolateral aspect.

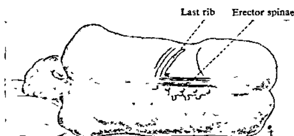


FIG. 87.—Posterior splanchnic block.

It should be noted that if the splanchnic block needle is inserted at an angle considerably more than 45° to the median body-plane there is the possible danger that it might enter the intervertebral

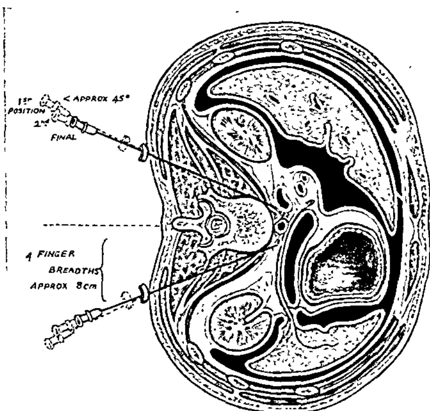


FIG. 88.—Bilateral posterior splanchnic block.

foramen where the injection of the anaesthetic solution would lead to disaster.

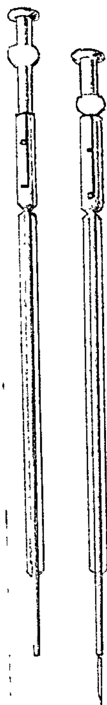


FIG. 86.—Kindersley's modification of Finsterer's splanchnic block needle.

(4) Posterior splanchnic block

Position of patient

The patient lies in the same position as for thoracic nerve block. The angle between the lower border of the twelfth rib and the outer border of the erector spinae group of muscles is palpated, and at its apex on each side an intradermal weal is raised to act as a landmark (Fig. 87). The large (12 centimetre) needle is then inserted through the weal at an angle of 45° to the median plane of the body, and with its bevel facing towards the spine. The needle is inclined slightly upwards (headwards) and advanced 8 to 10 centimetres according to the size of the patient, until it strikes the antero-lateral surface of the body of the first lumbar vertebra. It must pass beneath the lower border of the twelfth rib. The needle is then partly withdrawn and advanced again more tangentially to the vertebral body. This procedure is repeated until its point is felt to slide just past the body of the vertebra. The rubber recorder is then set 1 centimetre from the skin, and the point of the needle is advanced for this distance. If the position is correct the point of the needle will then be in the loose retroperitoneal tissue, in front of the body of the first lumbar vertebra and behind the lesser sac. The hub of the needle can be moved freely in the horizontal plane, but meets resistance in the vertical plane due to the great vessels and vertebral column. In this potential space lies the coeliac plexus which surrounds the origin of the coeliac artery (Kappis, 1918).

Technique

The syringe is charged with the 1 in 2,000 solution of Anethaine and adrenaline. If no blood issues from the needle, the syringe is firmly attached by a twisting motion. Two cubic centimetres of solution are now injected to clear away any obstruction in the needle. The aspiration test is then most carefully performed. If negative, the contents of the syringe are injected while taking care not to advance the needle. It is advisable to repeat the aspiration test at least once before discharging the syringe fully. In this manner five syringefuls should be injected (50 to 60 cubic centimetres of the 1 in 2,000 solution); then the procedure is repeated on the other side.

Aspiration test

Should the aspiration test be positive and blood be drawn into the syringe, it is most likely that the point of the needle has entered the inferior vena cava if on the right side, or the aorta if on the left side. In such cases the needle should be drawn back slightly until the aspiration test is negative. During the injection the piston moves freely as in an ordinary intravenous injection. This is a good sign, providing the

ANAESTHESIA—SPINAL

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1. DEFINITION

29.] Spinal anaesthesia is a particular form of regional anaesthesia. It is produced by injecting into the spinal canal a suitable drug which temporarily paralyses the sensory, motor and sympathetic nerves with which it comes into contact. Careful control of the drug enables the administrator to vary the extent of its action. It can be used to anaesthetize the whole body, to produce unilateral anaesthesia or to anaesthetize only a saddle-shaped area in the perineum. Its use is confined chiefly to operations below the diaphragm, although it is occasionally used for thoracic surgery.

2. CHOICE OF DRUGS

The first drug used for spinal anaesthesia was cocaine which, although efficient, was toxic in action. Synthetic drugs chemically allied to cocaine were found to be more satisfactory, and of these amylocaine hydrochloride, *B.P.* (Stovaine), and procaine hydrochloride, *B.P.*, *U.S.P.* XII (Novocain, Planocaine), have long been popular. Both these compounds give good anaesthesia for about an hour, after which their action wears off and, if the operation is not completed, either a second injection must be given or supplementary general anaesthesia must be administered.

Amylocaine hydrochloride

Procaine hydrochloride

Gliadin has been added to Novocain in order to prolong its action; gum acacia has similarly been added to Planocaine; the resulting solutions, known respectively as Spinocain and Duracaine, have been much used by some operators.

Addition of gliadin or gum acacia

Amethocaine hydrochloride (tetracaine hydrochloride, Anethaine, Decicain) is a more recent product of the cocaine group of drugs, and has an action which lasts about one and a half times longer than that of procaine hydrochloride (Novocain) (Maxson, 1938a).

Amethocaine hydrochloride

Bilateral splanchnic block

It is immaterial which side is injected first when performing bilateral splanchnic block in the above manner (Fig. 88). Injection of the left (lower) side is just as easy as that of the right, providing the patient is well to the edge, or slightly over the edge, of the table, and the anaesthetist is sitting on a stool. He can then work without having to bend down and manipulate the needle in an awkward position. The Kappis method is superior to the anterior approach for the following reasons.

(1) The block is inserted and has time to take effect before the operation has begun.

(2) The intra-abdominal manipulations of the anterior approach are avoided.

(3) The anterior approach cannot be performed efficiently except through an upper abdominal incision.

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[References to other titles are given under Anaesthesia in the Index Volume. The subject of Anaesthesia is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 472.]

Amylocaine hydrochloride (Stovaine) 10 per cent, sodium chloride 10 per cent: Chaput's solution.

Procaine hydrochloride (Novocain) 10 per cent, or solutions of procaine hydrochloride dissolved in the patient's cerebrospinal fluid.

Nupercaine 1 in 200, glucose 6 per cent: Heavy Nupercaine.

Amethocaine hydrochloride (Decicain) 10 per cent, nearly isobaric but probably slightly hyperbaric for many patients.

Light solutions

(*b*) *Those lighter than the cerebrospinal fluid* (*hypobaric*)

Nupercaine 1 in 1,500. Light Nupercaine.

Spinocain (Novocain with the addition of gliadin and alcohol).

Duracaine (Planocaine with the addition of gum acacia and alcohol).

Numerous techniques with various dosages have been described, and it is impossible to give a full list here. The following remarks may prove useful.

Dosage

For all-round work the heavy solution of Nupercaine can be strongly *recommended. Dosage is as follows.*

Operations on the upper abdomen	1·8–2 cubic centimetres.
Subumbilical operations –	1·4–1·6 cubic centimetres
Closed operations on the bladder	1 cubic centimetre
Perineal operations (low spinal)	0·8 cubic centimetre (*see* Fig. 90).

If the light solution of Nupercaine is used, 12–14 cubic centimetres should be injected for full abdominal anaesthesia. The dosage of procaine varies with different workers. A useful guide is to allow 75 milligrams for perineal surgery and 150–200 milligrams for work on the abdomen. Between five and ten minutes is required after injection for the drugs to exert their full action. In hot climates it has been found that it may be half an hour before anaesthesia is complete (Laurie, 1939). Why this is so is not clear.

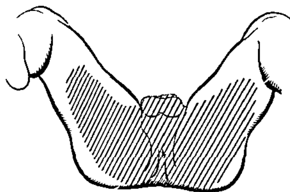


FIG. 90.—Low spinal anaesthesia. The shaded portion indicates the area anaesthetized, i.e. Nerves S2–S5 have been blocked. Suitable for perineal operations and for closed operations on the bladder.

3. TECHNIQUE

(1) Lumbar puncture

Position of patient

Although spinal anaesthesia has been produced by cisternal and dorsal punctures the method of choice is lumbar puncture. The patient is placed on the table in the lateral position with the knees drawn up and the head and shoulders well flexed. The spine should be horizontal or with a slight tilt head downwards. In an alternative position the patient sits on the table with his legs over the side and the feet resting on a stool; head and shoulders must be flexed and the elbows must rest on the knees. This position is used when (a) a

Nupercaine (Percaine)

Nupercaine (introduced in 1929 as Percaine) is a synthetic drug derived from quinoline. Used in strengths of 1 in 200 or 1 in 1,500 it produces anaesthesia for from two to three hours.

Chief solutions in use

As the distribution of the drug inside the spinal canal is largely dependent upon gravity, it is important to know how the specific gravity of any solution

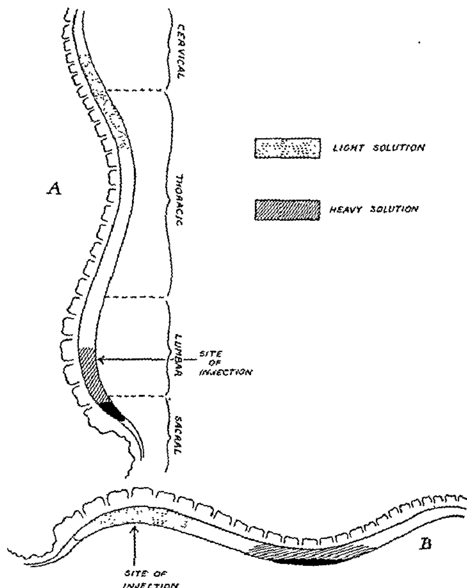


FIG. 89.—Diagram to show the distribution of light and heavy solutions inside the spinal canal when (a) the patient is upright and (b) lying on his back.

used will compare with that of the cerebrospinal fluid (*see* Fig. 89). The following list gives the chief solutions in use for spinal anaesthesia and their relative specific gravities.

(*a*) *Those heavier than the cerebrospinal fluid* (*hyperbaric*)

Heavy solutions

Amylocaine hydrochloride (Stovaine) 5 per cent, glucose 5 per cent: Barker's solution.

that there is a free flow between the syringe and the subarachnoid space. After this the solution is gently injected.

(3) Position of patient after injection

As soon as the injection has been completed the patient should at once be moved on to his back from the lateral position, and the table should be tilted slightly head downwards. Any hyperbaric solution which has been injected will then flow towards the mid-dorsal region. Height of anaesthesia will depend largely upon the quantity of solution injected. Adequate dosage will produce anaesthesia up to the nipple line. When the injection has been given to the patient in the sitting position the subsequent positions of the patient depend upon the type of solution used. When a heavy solution has been used for the purpose of inducing perineal anaesthesia the patient should remain seated upright for about a minute or two; he is then placed in the horizontal position. When light Nupercaine is used in order to produce anaesthesia of the abdomen the patient should sit upright as soon as the injection is completed, and should remain seated for 45 seconds from the time the injection was begun. At the end of this period he must immediately be placed on his back and the head of the table must be lowered. To receive an injection in unilateral anaesthesia the patient must lie on the side to be anaesthetized if a heavy solution is used, and with this side uppermost if a light solution is used. He should remain in this position for about ten minutes before he is moved. When a heavy solution is used the patient should not be placed in a steep Trendelenburg position until the solution has been fixed; from five to ten minutes should suffice for this.

After use of heavy solution

After use of light solution

Unilateral anaesthesia

4. MANAGEMENT OF CASE

(1) Pre-operative

Adequate premedication is desirable for patients undergoing operations under spinal anaesthesia. It allays nervousness and helps the patient to lie still while the operation is in progress. One-third grain (0·02 gramme) of Omnopon and $\frac{1}{150}$ grain (0·45 milligramme) Scopolamine (hyoscine) given hypodermically, together with 3 grains (0·2 gramme) of soluble pentobarbitone (Nembutal) orally, is suitable dosage for the ordinary robust adult. For elderly patients the pentobarbitone should be omitted. Premedication should be administered from one to one and a half hours before operation. It produces tranquillity in the patient and, in many cases, amnesia. Purgatives should not be given immediately before operation since liquid faeces in the rectum may be passed when the anal sphincter relaxes. A sedative may be given advantageously on the night before operation. Opinions differ on the desirability of telling the patient the nature of the anaesthetic. If information is asked for, the patient may be told that although he may feel some touch or pressure during the operation there will be no pain. It is desirable that the patient should have an empty stomach when a high spinal anaesthetic is to be given. An empty stomach is of less importance with a low spinal anaesthetic, and indeed for certain urinary operations, such as catheterization of the ureters, it may be an advantage to allow the patient to drink fluids while he is on the operation table in order to produce diuresis.

Drugs

Purgatives contra-indicated

Food

heavy solution is used to produce perineal anaesthesia or (b) light Nupercaine is used to produce abdominal anaesthesia.

Site of injection

When the skin over the lumbar region is to be prepared by application of iodine solution it is useful to mark the level of the iliac crests. The line joining these passes across the spine of the fourth lumbar vertebra, which serves as a landmark (*see* Fig. 91). The space between the third and the fourth lumbar spines is the best one through which to make the injection, although any of the lower lumbar spaces may be used. The injection should never be given higher than the first lumbar spine, otherwise damage may occur to the cord. The needle used should have a good point and a short bevel. A convenient thickness is size 20 or 21 measured by the Standard Wire Gauge. The needle should be inserted, with a slight tilt towards the head, in the midline of the body, and about half way between the tips of the spines limiting the space. As soon as the needle is felt to puncture the dura mater an additional push of one or two millimetres is given in order to ensure that the whole of the lumen is inside this membrane. Sometimes the point of the needle is felt to strike bone; this is usually the spine of the vertebra below the space, and indicates that the position of the needle is too near the horizontal plane. It should be withdrawn as far as the subcutaneous tissue and introduced again with a greater degree of tilt. If this procedure does not meet with success, it is often better to attempt to enter the same space from a slightly different position before another space is tried. Surgical asepsis must be maintained throughout.

Insertion of needle

Encounter with bone

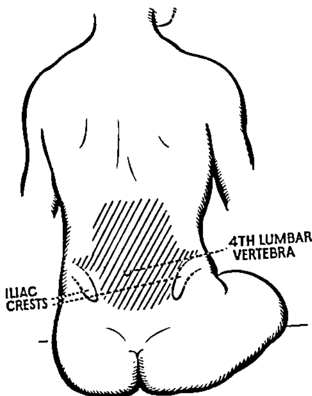


Fig. 91.—Preparation of the back with iodine (shaded portion). The line joining the iliac crests should be marked as this passes over the tip of L.4.

(2) Injection of drug

Withdrawal of spinal fluid

Before the anaesthetic solution is injected the operator must see clear cerebrospinal fluid issuing from the needle. If nothing comes out after the stilette is withdrawn, the needle should be rotated on its axis through 180°, or the stilette should be re-inserted in case the lumen is blocked. The presence of blood in the first flow may be disregarded provided the subsequent fluid becomes clear. As soon as the syringe containing the anaesthetic solution is connected to the needle, the piston should be gently withdrawn to make sure

drugs (for example Carbachol, 0·25 milligram) should be given. A small percentage of patients have headache after spinal anaesthesia as they do after diagnostic lumbar puncture. This usually occurs a day or two after the operation when the patient sits upright. It should be treated by continuance of the recumbent posture and by administration of drugs such as aspirin, or phenacetin and caffeine. Relief has been reported by Pickering (1939) after intrathecal injection of warm normal saline. The usual precautions must be taken with regard to hot-water bottles until sensation has returned to that part of the body affected by the anaesthetic.

Headache

5. COMPLICATIONS AND SEQUELAE

Headache and retention of urine have been dealt with in the previous section. Undue fall of blood-pressure demands an intravenous injection of ephedrine ⅓ grain (0·02 gramme) or 20–30 milligrams of Methedrine. The level of the table should be examined to make sure that the patient's head is on a lower level than is his trunk. In the rare event of phrenic paralysis—which should not occur with proper technique—artificial respiration must be maintained until the effect of the anaesthetic has worn off. Paralysis of the abducens nerve is an occasional sequela, but is always transient. Maxson (1938b) refers to Babcock and others who believe that the paralysis is due to imperfect aseptic technique. Permanent nerve palsies occur on rare occasions, and it is not always possible to find the exact cause. Some are the result of direct injury to the cord when the spinal puncture has been made too high up, and on one occasion absolute alcohol appears to have been injected in mistake for the light solution of Nupercaine.

Fall of blood-pressure

Paralysis

The occurrence of nausea and vomiting during the operation has already been mentioned on p. 250. They are seen more often in the conscious patient than in those who have had full premedication.

6. INDICATIONS AND CONTRA-INDICATIONS

It is difficult to be dogmatic about the indications for the use of a spinal anaesthetic because these are often matters of opinion among operators. To the enthusiast, a spinal anaesthetic is the anaesthetic of choice, but there is also the operator who goes to the opposite extreme. In general we may say that a spinal anaesthetic is indicated in the following circumstances.

Indications

(1) For lengthy operations which produce shock or which would require prolonged inhalation anaesthesia.

(2) For patients with pulmonary disorders which may be made worse by inhalation anaesthesia.

(3) For robust patients in whom easy relaxation under general anaesthesia may be difficult.

(4) For patients with diabetes or impaired function of the liver or kidneys.

(5) For many emergency operations when adequate preparation of the patient is impossible.

(6) For operations on the perineum and for closed operations on the bladder.

One can be a little more positive about the contra-indications to the use of a spinal anæsthetic. It should not be used in the following conditions:

Contra-indications

(1) For moribund patients.

Blood-pressure The patient's blood-pressure should be taken as a routine procedure before a spinal anaesthetic is administered. A small dose of ephedrine (¼ grain; 0·016 gramme) given intramuscularly just before the spinal injection helps to control the fall of blood-pressure.

(2) During the operation

As soon as the spinal injection has been given and the patient has been placed in position, the eyes should be bandaged. If cotton-wool is placed in the ears it should be moistened: dry cotton-wool does not keep out sound so well as it is supposed to do. If the anaesthetic is high enough to affect any part of the abdomen, the patient should be allowed one pillow only and the table should be kept tilted slightly head downwards throughout the operation. If a low spinal anaesthetic has been given, the table can be kept horizontal and the patient may have a second pillow if he wants it. A period of from five to ten minutes is usually long enough between the time of the spinal injection and the time of the first incision. If the surgeon is in doubt whether it is safe to start the operation, he should nip a portion of skin over the line of the incision with forceps and watch the patient's face at the same time; any painful sensation will be shown by movement of the facial muscles.

Fall of blood-pressure During the operation watch must be kept on the blood-pressure. A systolic pressure of less than 80 millimetres of mercury should be raised by administration of ephedrine or other pressor drug. In order to produce a rapid effect it should be injected intravenously. One-third grain (0·02 gramme) of ephedrine will produce an adequate rise, but the dose may have to be repeated when the effect has worn off. Good results have recently been reported from the use of the methyl derivative of desoxyephedrine (Methedrine) (Prescott, 1944). Intramuscular injections of 20–30 milligrams of this drug raised the blood-pressure and the rise was maintained for two hours.

Nausea Patients under high spinal anaesthesia occasionally experience nausea and sweating, which are usually transient. The condition sometimes coincides with the opening of the peritoneum and the placing of a pack in the upper abdomen, or with the application of traction to the sac which may occur during the repair of a hernia. Cold sponging of the patient's face and attention to the blood-pressure will bring relief, and the patient should be encouraged to take deep breaths.

(3) Post-operative

Posture When the operation has been completed, the Trendelenburg position, at a moderate degree of inclination, must be maintained while the patient is being returned to bed; a trolley which can be raised at one end is useful for this purpose. The foot of the bed should be kept raised on blocks for twenty-four hours. If the patient finds this position irksome he may be placed horizontally when the effect of the anaesthetic has worn off, but he should have only one pillow. He should be discouraged from adopting a sitting posture until the twenty-four hours are past. Fluids may be given by mouth at any time after the patient is back in bed unless the nature of the operation contra-indicates this. *Bladder* The bladder must not be allowed to become over distended. The use of a catheter may be necessary on the day of operation, but if there is subsequent difficulty in micturition an injection of one of the acetylcholine group of

of treating eclampsia. There are also recent reports of its value in the treatment of pulmonary oedema (Sarnoff, 1944). Since it dilates the blood-vessels and lowers the blood-pressure, it appears to give the same benefits as does venesection.

In other conditions

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[References to other titles are given under Anaesthesia in the Index Volume. The subject of Spinal Anaesthesia is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 491.]

(2) For badly shocked patients, with the possible exception of those with a crush injury to the leg.

(3) For operations above the diaphragm, with the exception of thoracic operations for which a unilateral anaesthesia is used. The whole body can be and has been anaesthetized by means of a spinal injection, but there is the added risk of phrenic paralysis.

(4) For patients who have a septic lesion over the lumbar region.

(5) When the patient has very decided objections to it and there is no contra-indication to a general anaesthetic.

Other considerations

The following points are also worth consideration:

(1) Patients with a disease of the central nervous system may blame the anaesthetic if the disease subsequently becomes worse.

(2) It may be difficult to perform lumbar puncture in patients with marked scoliosis or who are abnormally fat.

7. ADVANTAGES

Simplicity

Spinal anaesthesia has certain clearly defined advantages over general anaesthesia. It is a relatively simple procedure, and it requires only a small amount of apparatus. It provides excellent relaxation of the muscles, thereby assisting ease of operation; this is often commented on by surgeons who perform abdominal operations under both general and spinal anaesthetics. It is a great boon to an operator, such as a medical missionary or a ship's surgeon, who may have to work without a competent anaesthetist or with unskilled assistants. Spinal anaesthesia is relatively non-toxic and may therefore be used with safety in the presence of diseased liver or kidneys. It enables the patient to take food and fluids sooner than after general anaesthesia. The period of convalescence is often shortened: although this may be a matter of only a day or two it makes a notable difference to the annual turnover in a busy surgical ward.

Non-toxicity

Early feeding

Short convalescence

8. THERAPEUTIC USES

Spinal anaesthetics have some value as therapeutic agents. It is chiefly their action on the sympathetic nerves which makes them useful in this respect. In operations on the alimentary tract, patients with both cardiospasm and congenital megacolon (Hirschsprung's disease) have been given spinal anaesthetics and in the latter condition there have been some encouraging results. It has been used to relieve distension due to paralytic ileus. For example, an ileus developed in a patient with haematomyelia and he became very much distended. A spinal anaesthetic was given and within five minutes a large quantity of flatus passed, producing considerable relief.

In cardiospasm and congenital megacolon

In paralytic ileus

In vascular disorders

In vascular disorders such as thrombo-angiitis obliterans, spinal anaesthesia gives useful information whether a sympathectomy will benefit the condition. If a spinal anaesthetic is given in such a case and the temperature of the limb rises, it shows that sympathectomy will be of value; the operation can be performed under the existing anaesthesia. It has also been used for the purpose of reducing the blood-pressure in extreme hypertension, but it is doubtful whether this can be of more than temporary value.

Spinal anaesthesia has been advocated by Paramore (1928, 1930) as a method

It has been observed that adrenaline, cold and emotion can produce the pains of angina of effort and spasmodic angina, which are relieved by nitrites. This suggests that interruption of sympathetic efferent pathways may also be of importance and must be held responsible for the relief which has sometimes followed excision of the superior cervical ganglion, since the superior cardiac nerve is believed to contain only efferent fibres.

Interruption of sympathetic efferent pathways

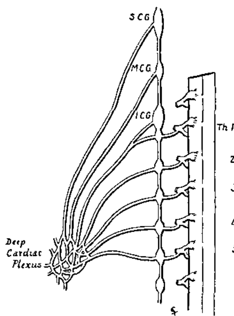


Fig. 92.—Afferent pathways for cardiac pain. (The superior cardiac nerve contains only efferent fibres). S.C.G. = superior cervical ganglion. M.C.G. = middle cervical ganglion. I.C.G = inferior cervical ganglion.

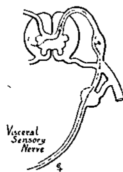


Fig. 93.—Afferent pathway for visceral pain.

3. MORBID ANATOMY

The essential lesion underlying angina of effort is narrowing of a branch of the coronary arterial tree. If the lesion is severe enough to render the blood flow inadequate at rest, secondary changes are produced in the muscle nourished by the vessel involved; in milder cases even of long standing the heart may not, however, show trophic changes. The amount of damage bears no constant relationship to the severity of the pain; an individual with a low threshold for pain may suffer from severe angina for years before myocardial change becomes demonstrable, and vice versa.

Variability of lesion

Either coronary atheroma or syphilitic aortitis is present in nearly every case. Coronary atheroma may be the only demonstrable vascular lesion in the body; it may be localized to within an inch or so of the coronary orifices or may be widespread and associated with severe patchy myocardial fibrosis.

Coronary atheroma

In syphilitic aortitis the mouths of the coronary arteries are apt to become nipped, in the earlier stages by inflammatory swelling and later by fibrosis. It is important to note that although the myocardium is thus deprived of an adequate blood supply it is not itself attacked by the spirochaete.

Syphilitic aortitis

ANGINA PECTORIS

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1. DEFINITION AND AETIOLOGY

30.] The term, angina pectoris, has been used to cover angina of effort, spasmodic angina, coronary infarction and pain of an innocent type, but for only the first two of these is surgical treatment indicated. Angina of effort is analogous to intermittent claudication, and is due to cardiac ischaemia, which must be local to produce pain; general anoxaemia of the heart, as in congestive failure with mitral stenosis, does not cause angina of effort.

2. ANATOMY AND PHYSIOLOGY

Course of pain fibres

The nerves which conduct pain impulses from the heart to the brain are similar to somatic afferent fibres, but they are incorporated in the sympathetic cardiac nerves. They arise from periarterial and epicardial endings in the heart and run via the deep and superficial cardiac plexuses and the middle and inferior cardiac nerves to the middle and inferior cervical ganglia. They pass uninterrupted through these ganglia and through the upper ganglia of the thoracic sympathetic trunk to enter the upper five thoracic spinal nerves in the white rami communicantes. There is good evidence that other afferent fibres pass direct from the deep cardiac plexus to the upper five thoracic ganglia to reach the same white rami. (*See* Figs. 92, 93.)

The further course of these fibres is to their parent cells in the posterior spinal root ganglia and thence through a synapse, across the cord and upwards in the spinothalamic tract.

6. DIFFERENTIAL DIAGNOSIS

Classical cases of angina of effort do not present any difficulty in diagnosis; pain which simulates angina, however, may deceive even the expert, and in order to avoid disappointment for both his patient and himself, the surgeon will be well advised to obtain the opinion of a physician who has made a special study of the subject. "Functional" or psychogenic pain, for which one of us (G. B.) has introduced the rather controversial term *angina innocens*, may be very acute and in its distribution it may closely resemble angina of effort. The cardiovascular system may be normal, but this type of pain can result from anxiety in a patient who has heart disease, commonly mitral stenosis. The quantitative relationship to exercise is lacking, pain is more often brought on by mental or physical fatigue than by exertion itself, fainting is common and the left side of the chest is often hyperaesthetic. Psychological disturbance is nearly always present, and surgical treatment is valueless.

Angina innocens

There are two diseases which may manifest themselves by angina of effort—coronary infarction and syphilitic aortitis. The latter may be recognized by the smooth tube-like stretching of the aorta seen on the x-ray screen, by the Wassermann reaction and by the relief afforded by antisyphilitic treatment. The former gives rise to pain which, although very violent at first, usually subsides and disappears in a few days or weeks.

Coronary infarction and syphilitic aortitis

On account of the fact that symptoms are often more severe after meals, dyspepsia may be blamed for their occurrence.

Dyspepsia

Angina of effort may be produced, in a predisposed individual, by any form of anaemia and a blood examination is therefore important.

Anaemia

7. INDICATIONS FOR SURGICAL INTERVENTION

Surgical treatment is indicated when a sufficiently long course of medical treatment—rest in bed, reorganization of life and activity, attention to diet, medication with sedatives and nitrites, and the management of associated conditions such as diabetes, dyspepsia, anaemia, chronic bronchitis—has failed to prevent the pain from increasing, thus interfering with the patient's work, comfort or happiness. Less than 2 per cent of patients with angina suffer pain of this degree of severity.

Cases suitable for operation

The symptoms quite commonly wax and wane, and operation is contra-indicated if the pain, although severe, is diminishing in severity. Surgical treatment should not be undertaken if the state of the myocardium is poor, if coronary infarction has occurred within the previous six to twelve months and if active syphilitic aortitis or other complicating conditions such as renal or liver disease coexist. In the absence of these diseases, however, it is remarkable how well patients with angina can stand operation.

Contra-indications

8. PRE-OPERATIVE MANAGEMENT

The beneficial effect of a period of rest in bed need scarcely be stressed; it also affords time for the treatment of any associated disease such as diabetes. Sedative drugs are valuable, and apprehension immediately before the

Rest

Aortic regurgitation

Aortic regurgitation, whether syphilitic or rheumatic, may be another cause of interference with the coronary flow; anaemia and thyrotoxicosis may be exciting factors in patients already suffering from coronary disease.

4. CLINICAL PICTURE

Angina of effort

A prolonged investigation of 112 patients with angina of effort brought out the following clinical features (Bourne and Scott, 1938).

Eighty per cent of the patients are men, and 80 per cent of these are between the ages of fifty and seventy years. The onset is characterized by a sense of pressure during exertion, which on further exertion develops into pain which may be a dull ache or a feeling of constriction or of bursting. It is central under the upper sternum in 80 per cent, left-sided in 17 per cent and right-sided in only a few cases. Radiation to the left arm or to both arms is common (40 per cent) and in a few the right arm alone is affected. In 25 per cent the pain comes on more readily after a meal.

Patients who understand the quantitative relationship between exercise and pain take care to avoid exertion likely to render the pain acute. When exercise ceases, relief is obtained almost immediately, although there may be an interval of up to fifteen minutes before the pain subsides. A few patients can "walk off" the pain—it may be that coronary spasm is relaxed by further exercise.

Spasmodic angina

Spasmodic angina is often severe, being brought on by exercise, emotion, cold, or a digestive upset, and once started it has to run its course. This pain may account for an increase in the severity of angina over a period of months or years and may give rise to the old-fashioned text-book picture of the patient frozen into immobility.

Both angina of effort and spasmodic angina are relieved by nitrites.

5. SPECIAL AIDS TO DIAGNOSIS

Electrocardiogram

In many cases of coronary disease the electrocardiogram shows persistent R–T or S–T deviation in leads I, II, III and especially in lead IV. If absent during rest these changes may be brought out by exercise or by breathing 10 per cent oxygen, although these measures entail some slight risk.

Innocent or "functional" angina may be distinguished from angina of effort by the relief of the latter condition by nitrites and its accentuation by adrenaline, 3 minims of the solution given hypodermically, or by thyroxine.

X-ray

The size and shape of the heart may be checked by orthodiagraphy; x-ray screening to investigate the capacity of the various chambers of the heart and the condition of the aorta, lungs and mediastinum, together with the study of a six-foot film, may be of value.

Tests

The Wassermann reaction is positive in from 70 to 80 per cent of all cases of cardiovascular syphilis; the sedimentation rate and the leucocyte count are raised by a recent coronary infarction.

It must be remembered that coronary disease may cause sudden death without having produced signs which can be detected even by special methods of investigation.

intimately bound together and the greatest care must be taken to avoid damage to the nerve. It is usually exposed at this stage of the operation, and may be found superficial to the inferior thyroid artery or embedded in the gland. Another point at which the nerve is even more liable to injury is one near the upper pole, where it is closely related to the inferior cornu of the thyroid cartilage. (*See* Figs. 97, 98, 99, 100.)

Danger to recurrent laryngeal nerve

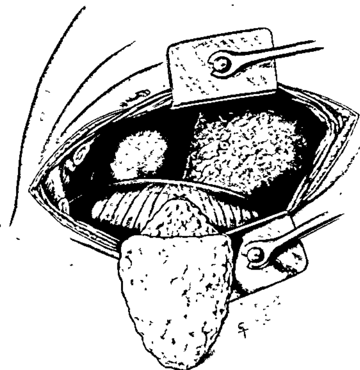


Fig. 95.—Cardio-omentopexy. First stage. (*O'Shaughnessy.*)

Once the posterior border has been cleared and the nerve defined, the freeing of the rest of the lobe is easy; a similar procedure must then be carried out on the other side, and finally care must be taken to remove completely the pyramidal lobe.

(3) Sympathectomy

(*a*) *Alcohol injection*

Interruption of the nervous pathways may be achieved by alcohol injection of the upper five white rami communicantes. This method is employed when advanced age or concomitant disease forbids excision of the nerves, and has been perfected by White (1942). Bilateral injection may be required, but it is often sufficient to inject the side to which the pain is referred.

Paraldehyde per rectum

operation should be abolished by the rectal administration of paraldehyde (45 minims per stone of body weight; maximal dose 360 minims).

9. OPERATIONS

(1) Revascularization of the heart

Bearing in mind the fundamental causes of angina of effort—coronary sclerosis, thrombosis or embolism, and syphilitic aortitis which narrows the lumen of the coronary arteries—the rational treatment would appear to be the provision of a new blood supply. This has been attempted by grafting the pectoral muscles (Beck, 1936) or the great omentum (O'Shaughnessy, 1937) on to the heart. The object of the graft is threefold: to revascularize the ischaemic cardiac muscle and to provide collateral channels not only between the heart and the mediastinum, but also between the right and left coronary arteries. (*See* Fig. 94.)

Pectoral or omental graft

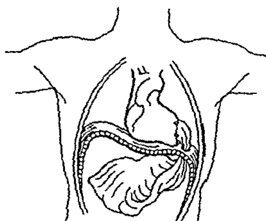


FIG. 94.—Cardio-omentopexy. Diagram to show method. (*O'Shaughnessy.*)

Stages of operation

The incision for cardio-omentopexy is made from the midline to the anterior axillary line in the left fifth intercostal space. The pleural cavity is opened, the fifth and sixth costal cartilages are cut through, and the edges of the wound are retracted widely enough to expose the diaphragm and the pericardium. The phrenic nerve is crushed. Through an incision in the diaphragm a suitable portion of the omentum is brought up into the chest and the wound in the diaphragm is closed around it. (*See* Fig. 95.)

The pericardium is then opened and the omentum is sutured to the surface of the heart and to the edges of the pericardium with fine linen thread (*see* Fig. 96). The chest is then closed.

(2) Total thyroidectomy

By diminishing the metabolic activity of the body the work of the heart may be reduced below the pain-producing limit. Pain is relieved, however, before metabolism is appreciably affected, and it may be that other factors are involved—perhaps the interruption of nervous pathways during the operation, and also the effect of thyroxine lack in decreasing the sensitivity of the heart to adrenaline.

Associated factors

Stages of operation

The thyroid gland is exposed in the usual manner and the deep cervical fascial sheath is gently stripped off the surface of one lateral lobe until the middle thyroid vein and the superior thyroid vessels are defined; these are ligated and divided. The inferior pole is then stripped and the lobe having been lifted forwards, the branches of the inferior artery are picked up with mosquito forceps and divided on the capsule of the gland. As Berlin (1935) has pointed out, there is often a very adherent zone in which thyroid gland, trachea, recurrent laryngeal nerve and inferior thyroid artery are

each of these points in turn a long fine needle is inserted first at right angles to the skin surface until the lower border of the corresponding rib or

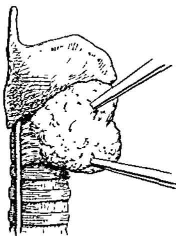


FIG. 99.—Total thyroidectomy. Recurrent laryngeal nerve exposed to show its close relation to the inferior cornu.

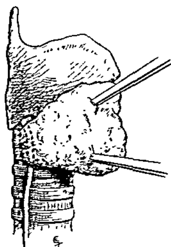


FIG. 100.—Total thyroidectomy. Recurrent laryngeal nerve embedded in the gland.

transverse process is reached, and then below the bone edge medially and slightly downwards for about 3 centimetres until the lateral aspect of the vertebral body is felt. The needle should not be attached to a syringe, so that an escape of blood or cerebrospinal fluid can be recognized; when the needle is satisfactorily placed the syringe is attached and suction is applied to confirm its position. Two

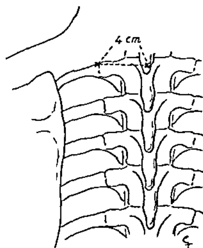


FIG. 101.—Alcohol injection. Relation of the spine of the seventh cervical vertebra to the transverse process of the first thoracic.

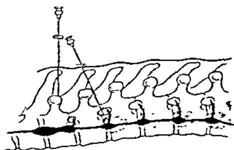


FIG. 102.—Alcohol injection. Shows the downward inclination of the needle below the transverse process and towards the corresponding sympathetic ganglia.

cubic centimetres of the procaine and adrenaline solution is injected through each of the five needles and the signs of sympathetic paralysis are looked for; when they appear, a further 3 cubic centimetres of the solution should be injected through every needle to render the alcohol injection completely painless. Finally 5 cubic centimetres of 95 per cent

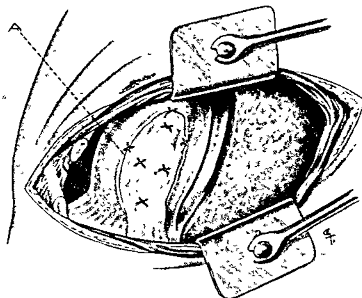


FIG. 96.—Cardio-omentopexy. Second stage. A: Cut edge of pericardium. (*O'Shaughnessy.*)

Technique

The patient lies in bed (so as to avoid subsequent movement with the risk of spreading alcohol in the tissues) with the spine straight and the head

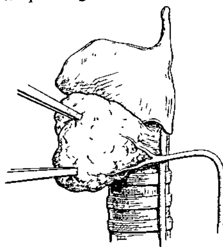


FIG. 97.—Total thyroidectomy. Relations of recurrent laryngeal nerve. Nerve deep to the left inferior thyroid artery.

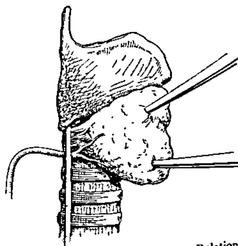


FIG. 98.—Total thyroidectomy. Relations of recurrent laryngeal nerve. Nerve superficial to inferior thyroid artery.

slightly flexed. The seventh cervical and the upper four thoracic vertebral spines are marked and superficial injections of 0·5 per cent procain solution with adrenaline are made at points 4 centimetres directly lateral to them. Through

pain. After alcohol injection intercostal neuritis is inevitable and requires palliation, perhaps for some weeks.

Intercostal neuritis

Although a successful sympathectomy removes the "danger signal" of anginal pain the risk of sudden heart failure is not sufficient to contra-indicate this method of treatment. The heart may share in the improvement in the general health which results from the relief of pain, and if exertion is excessive the patient is often conscious of a curious sensation in the chest, sometimes associated with palpitation and sweating, which acts as a painless warning.

Possibility of cardiac improvement

11. RESULTS OF SURGICAL TREATMENT

Although O'Shaughnessy reported favourably on the effects of cardio-omentopexy, in our experience of 4 cases the operation has not proved successful. In 2 cases a thorough post-mortem examination, 1 and 2 years afterwards respectively, failed to reveal any vascular anastomosis.

Total thyroidectomy has met with success in 17 out of 20 cases, especially in the nervous, lean and worried type of patient, and in the presence of aortic incompetence. Relief has been maintained up to 5 years after operation, and our experience agrees with White and Smithwick's dictum that total thyroidectomy is still the best method of decreasing the motor activity of the heart. In the 3 less successful cases pain returned in 6 months but was much less in degree.

Total thyroidectomy

Our experience with alcohol injection bears out that of White and Smithwick, whose results in 70 cases show complete relief in 50 per cent and reduction to a mild and manageable form of angina in another 30 per cent. One very successful case was that of an obese woman whose pain had reached a condition of acute *status anginosus*, one spasmodic attack following on another; her weight rendered any operation hazardous and all other measures had failed, but she was entirely relieved by alcohol injection.

Alcohol injection

Thoracic sympathectomy by Raney's technique has been successful in one case, partially so in two others; a fourth patient died with pleural effusion and underlying pulmonary consolidation a few days after the operation. Leriche's figures for stellate ganglionectomy gave in 26 per cent of cases excellent results, in 15 per cent great improvement and in 26 per cent failures. We have not found statistics of any large group treated by the anterior operation extended to include the upper thoracic ganglia, but many surgeons have had experience of the good results obtainable by this method, which is preferable to stellate ganglionectomy alone.

Thoracic sympathectomy

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[References to other titles are given under Angina Pectoris in the Index Volume. The subject of Angina Pectoris is dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 547.]

alcohol is injected slowly through each needle in turn. (*See* Figs. 101, 102, 103.)

(*b*) *Ganglionectomy and trunk section*

This may be carried out by a posterior or an anterior approach.

Technique

Posterior approach.—The operation is a modification of that described by A. K. Henry. The skin incision is parallel to and 4 centimetres from the midline on the side to which the pain is referred, and is made to expose the posterior ends of the third, fourth and fifth ribs, which are excised from their angles to their heads. The intercostal vessels having been secured, the pleura is gently stripped forwards so as to expose the lateral sympathetic trunk from the fifth thoracic ganglion below to the stellate ganglion above.

The whole of this portion of the trunk may be excised, but Raney (1939) has recorded satisfactory results after the division of the trunk below the fifth thoracic ganglion and the rami communicantes of the fourth, third and second thoracic ganglia, leaving those to the first ganglion intact so as to avoid a Horner's syndrome. The freed portion of the trunk is then turned upwards and buried in the spinal muscles to prevent regeneration.

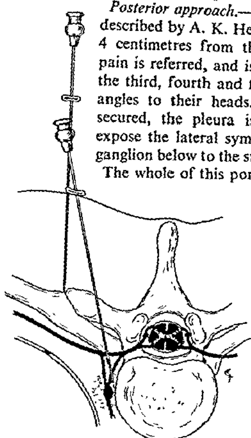


FIG. 103.—Alcohol injection. Medial inclination of the needle beyond the transverse process to reach the side of the vertebral body close to the sympathetic rami.

Technique

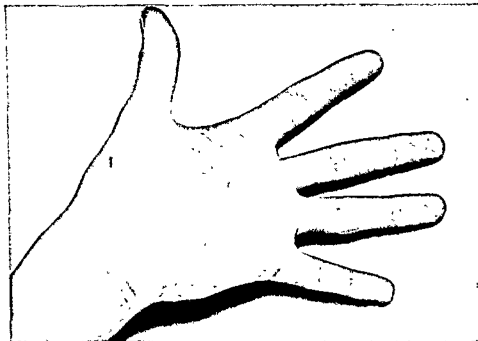
Anterior approach.—The inferior cervical and upper three thoracic ganglia are exposed by a low collar incision, division of the scalenus anterior muscle and downward retraction of the subclavian artery—the usual anterior approach used in cervico-thoracic sympathectomy for other conditions. Leriche has obtained good results from removal of the stellate ganglion alone, but it seems preferable to remove as much of the lateral trunk as may be reached with safety from the front.

In order to avoid a Horner's syndrome the stellate ganglion and the rami of the first thoracic ganglion must be left intact, but to block all the nerves it is necessary to sacrifice these structures. Although the fourth and fifth ganglia can be reached only from behind, the posterior approach is a much more severe operation. For this reason and because the effects of its use are practically as good, the anterior approach is preferable.

10. POST-OPERATIVE CARE

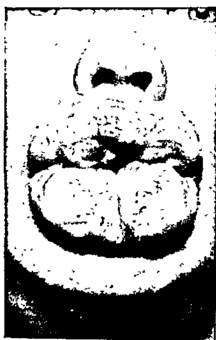
Pleural effusion

After cardio-omentopexy an effusion into the left pleural cavity may require to be aspirated. After total thyroidectomy sufficient thyroid extract must be given to prevent myxoedema, but an overdose will cause a return of anginal



Cavernous haemangioma of palm of hand showing characteristic blue coloration. Suitable for surgical excision. (*Colour photo by Hennell, The Metal Box Co. Ltd.*)





Lymphangiomatous macroglossia and macrochelia. Patient of Mr. E. K. Martin, University College Hospital. (*Colour photo by Hennell, The Metal Box Co. Ltd.*)

PLATE II

ANGIOMA

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1. DEFINITION AND AETIOLOGY

31.] An angioma is a tumour composed of blood-vessels (hæmangioma) or lymph vessels (lymphangioma). The majority of tumours pursue a benign course and are slowly progressive. Of unknown aetiology, they are either present at birth or noticed soon after; in a few cases the tumours appear in adult life.

Development of lesions

The lesions develop from embryonic mesodermal tissue destined to form blood-vessels or lymphatic vessels, by buds of endothelium which become canalized. The blood supply to the tumour is limited to one or two afferent and efferent vessels. As the tumour grows it compresses and sometimes

obliterates the adjacent vascular supply of the surrounding tissues, and does not form large anastomotic channels with the normal blood-vessels.

2. MORBID ANATOMY

There are several distinct varieties of angioma. They vary in their clinical appearance, pathology and course. The treatment suitable for some is contra-indicated in others. The following classification is that on which the choice of treatment is based.

(1) Haemangioma

Five common varieties are described, as follows:

(*a*) *Capillary haemangioma* (*strawberry mark*)

This type is bright red in colour, slightly raised from the surface, circumscribed in extent. Two or more tumours may be present. They grow fairly rapidly. The tumour consists chiefly of small capillaries; it blanches slowly



FIG. 104.—Capillary haemangioma showing central area of scarring due to previous treatment with solid carbon dioxide. The lesion was successfully treated with interstitial radon seeds.



FIG. 105.—Same patient as shown in Fig. 104 illustrating combination of capillary and cavernous types of angioma.

and incompletely on pressure. This type is also known as "strawberry mark" or "naevus vasculosus" (*see* Figs. 104 and 105). It varies in size from a minute red spot to one of several centimetres in diameter. It is a cutaneous lesion and occurs on the face, neck, shoulder, back, chest or abdomen, and less commonly on the limbs. Although the lesion is universal in distribution the face is the commonest site.

Sites

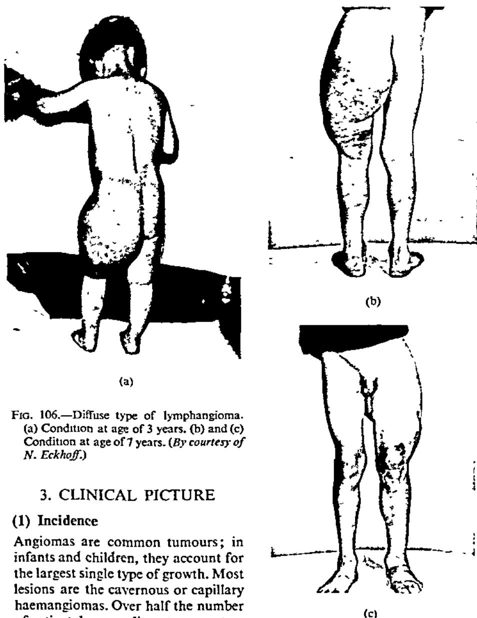
(*b*) *Cavernous haemangioma*

Blue or purple in colour, diffuse, irregular in shape, soft and easily compressible, these tumours are composed of sinuses lined by endothelium and contain venous blood (*see* Plate II). They follow a slowly progressive course. Of wide distribution, they may be found in any tissue or organ. The commonest sites are the skin and subcutaneous tissue, the muco-cutaneous junction at the lip, or the conjunctiva. In the mouth the lesion is diffuse and affects the buccal mucosa, floor of the mouth, gums and tongue, more rarely the nasopharynx and larynx. In the mouth and upper air passages the tumours form blue masses raised from the surface; occasionally they have a broad pedicle. In this situation they are not uncommonly associated with subcutaneous

Commonest sites

and fasciae. It frequently affects an entire limb. The tumour is diffuse, spongy in consistency, but not compressible. The lower limb is affected more frequently than the upper limb. The skin shows changes similar to those found in cavernous lymphangioma and, in patches, those of haemangioma of various types. (*See* Fig. 106.)

Skin change



(a)

(b)

(c)

Fig. 106.—Diffuse type of lymphangioma. (a) Condition at age of 3 years. (b) and (c) Condition at age of 7 years. (*By courtesy of N. Eckhoff.*)

3. CLINICAL PICTURE

(1) Incidence

Angiomas are common tumours; in infants and children, they account for the largest single type of growth. Most lesions are the cavernous or capillary haemangiomas. Over half the number of patients have a solitary tumour; two tumours are not infrequent; multiple lesions are found in 25 per cent of cases.

There is a marked sex incidence: 65 per cent of angiomas occur in females.

Incidence

The common varieties are noted at birth or soon after—within a few days. Lesions developing during the first year of life are probably also congenital but are so small at birth as to be overlooked. After the first year of life fresh

cavernous haemangiomas in the front or lateral aspects of the neck; the deep and superficial lesions usually communicate by well-defined, thin-walled vessels. Visceral lesions are found in the liver, spleen and kidney and sometimes the small intestine. Skeletal tumours are most common in the vertebrae, with a predilection for the lumbar and sacral regions of the spine; these give rise to the characteristic *x*-ray appearance of "vertical striation". Cavernous haemangiomas form a small proportion of tumours of muscle, the commonest group affected being the quadriceps extensor. They have also been found in the synovial membrane of large joints and in association with dyschondroplasia. (Angioma of the brain and meninges is dealt with elsewhere.)

(c) Port-wine stain (naevus flammeus)

This lesion is always cutaneous, well delimited, not raised from the surface, and deep purple or mauve in colour. It is always noticed at birth and does not grow except in proportion to the general growth of the patient. The commonest site is the face, and the areas of distribution of the various branches of the trigeminal nerve not infrequently correspond with the extent of the naevus.

Commonest site

(d) Racemose (arterial) haemangioma—cirsoid aneurysm

Characteristics

This type is characterized by its appearance in adult life, its rapid progress and the pulsation of the lesion. It is composed of thickened tortuous vessels containing arterial blood. Unlike other types the tumour has wide and numerous communications with surrounding normal arteries. It is bluish-red in colour and pulsatile, and has been compared to a writhing mass of earthworms. The commonest site is the subcutaneous tissue of the neck and the scalp. The tumour is fed by the external carotid artery or one of its main branches. Occasionally a racemose haemangioma is found in the limbs.

Commonest site

(e) Compact haemangioma

This type, also described as angioblastic or hypertrophic haemangioma, is a solid or partly cystic non-compressible elastic subcutaneous tumour. It consists of vessels in which the endothelial lining has undergone proliferation, and so obliterated the vascular channels. The skin over it is thinned and the tumour forms a pale-blue subcutaneous mass.

(2) Lymphangioma

There are two common varieties, as follows:

(a) Cavernous lymphangioma

Sites

This consists of sinuses and cyst-like spaces lined by endothelial cells and containing lymph. The lesions occur in the skin and mucous membrane in the form of a diffuse or circumscribed tumour, causing enlargement of the affected part. In the skin the tumour is composed of a series of papules or vesicles, firm in texture, slightly brown in colour. They grow slowly. In the mouth the mucosa and muscular tissue are involved by infiltration and lead to great enlargement of the tongue (macroglossia) or lips (macrochelia). (*See* Plate II.)

(b) Diffuse systemic lymphangioma

In soft tissues

This type consists also of dilated lymph vessels and newly formed lymph spaces which infiltrate all the soft tissues—skin, subcutaneous tissue, muscles

and fasciae. It frequently affects an entire limb. The tumour is diffuse, spongy in consistency, but not compressible. The lower limb is affected more frequently than the upper limb. The skin shows changes similar to those found in cavernous lymphangioma and, in patches, those of haemangioma of various types. (*See* Fig. 106.)

Skin chang

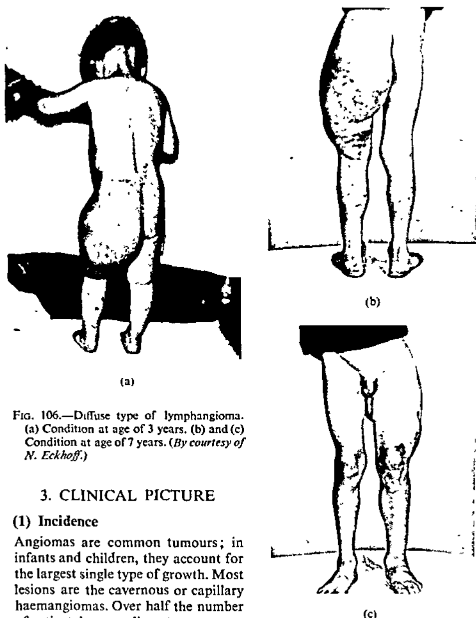


FIG. 106.—Diffuse type of lymphangioma. (a) Condition at age of 3 years. (b) and (c) Condition at age of 7 years. (*By courtesy of N. Eckhoff.*)

3. CLINICAL PICTURE

(1) Incidence

Angiomas are common tumours; in infants and children, they account for the largest single type of growth. Most lesions are the cavernous or capillary haemangiomas. Over half the number of patients have a solitary tumour; two *tumours are not infrequent; multiple lesions are found in 25 per cent of* cases.

There is a marked sex incidence: 65 per cent of angiomas occur in females.

Incidence

The common varieties are noted at birth or soon after—within a few days. Lesions developing during the first year of life are probably also congenital but are so small at birth as to be overlooked. After the first year of life fresh

cavernous haemangiomas in the front or lateral aspects of the neck; the deep and superficial lesions usually communicate by well-defined, thin-walled vessels. Visceral lesions are found in the liver, spleen and kidney and sometimes the small intestine. Skeletal tumours are most common in the vertebrae, with a predilection for the lumbar and sacral regions of the spine; these give rise to the characteristic x-ray appearance of "vertical striation". Cavernous haemangiomas form a small proportion of tumours of muscle, the commonest group affected being the quadriceps extensor. They have also been found in the synovial membrane of large joints and in association with dyschondroplasia. (Angioma of the brain and meninges is dealt with elsewhere.)

(c) Port-wine stain (naevus flammeus)

This lesion is always cutaneous, well delimited, not raised from the surface, and deep purple or mauve in colour. It is always noticed at birth and does not grow except in proportion to the general growth of the patient. The commonest site is the face, and the areas of distribution of the various branches of the trigeminal nerve not infrequently correspond with the extent of the naevus.

Commonest site

(d) Racemose (arterial) haemangioma—cirsoid aneurysm

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This type is characterized by its appearance in adult life, its rapid progress and the pulsation of the lesion. It is composed of thickened tortuous vessels containing arterial blood. Unlike other types the tumour has wide and numerous communications with surrounding normal arteries. It is bluish-red in colour and pulsatile, and has been compared to a writhing mass of earthworms. The commonest site is the subcutaneous tissue of the neck and the scalp. The tumour is fed by the external carotid artery or one of its main branches. Occasionally a racemose haemangioma is found in the limbs.

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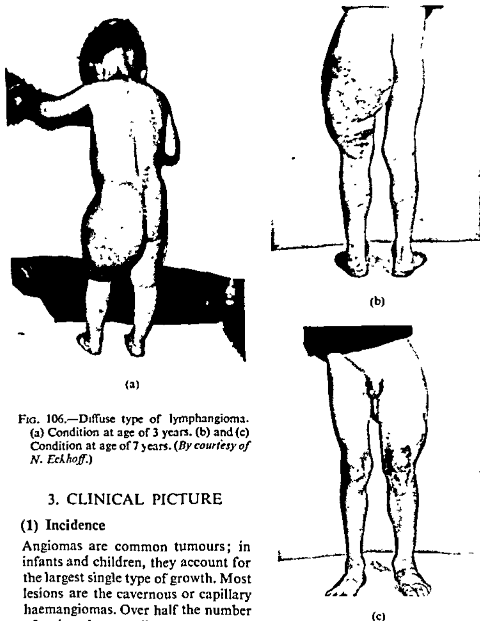


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3. CLINICAL PICTURE

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There is a marked sex incidence: 65 per cent of angiomas occur in females.

Incidence

The common varieties are noted at birth or soon after—within a few days. Lesions developing during the first year of life are probably also congenital but are so small at birth as to be overlooked. After the first year of life fresh

tumours develop but rarely, with the exception of the arterial and compact varieties. The port-wine stain is invariably present at birth. Lymphangioma is very much rarer than haemangioma.

(2) Tissues involved

The cutaneous and subcutaneous variety form the bulk of lesions; next in order of frequency are the mucosal and submucosal tumours of the lips and mouth. All other sites are rarities and are noted mostly in adult life; of these the skeletal and muscle lesions are examples. The association of superficial and deep tumours is seen in certain situations, such as the subcutaneous lesions of the neck and face with those of the larynx, and skin and muscle tumours specially in the thenar and hypothenar parts of the hand. (*See* Plate II.) In lymphangiomatous tumours, both in the cavernous and the diffuse systemic varieties there is frequently an element of haemangioma; this is nearly always the case in macroglossia; cutaneous haemangiomas are also found in patchy distribution in the diffuse lymphangioma affecting a whole limb.

Superficial and deep tumours

Associated haemangioma

(3) Distribution of lesions

In most reported large series of cases there is a great preponderance of lesions on the face and neck—about 55 per cent—yet this area accounts for less than one-seventh of the body surface. The trunk shows as many lesions on the chest and abdomen as on the back; the extremities show an incidence of 15 per cent.

(4) Rate of growth

Capillary haemangioma

Capillary haemangiomas grow rapidly, specially during the first year of life. They increase in all dimensions and the long diameter of the lesion generally follows the natural creases of the skin; increase in size is much greater than the general rate of growth of the child. The treatment of such lesions is, therefore, a matter of urgency. The cavernous angioma grows much more slowly, and may take as many years as the capillary lesion takes months, for a corresponding increase in size. The port-wine stain, although the most unsightly of all angiomas, is relatively static; its rate of growth is only proportional to the general rate of growth; in adults it never extends peripherally although it may become raised from the surface by the development of a superimposed cavernous angioma. The rare racemose haemangioma grows rapidly, and its local penetrating and invasive character shows clinically, but not histologically, a degree of aggressiveness comparable to that of malignant mesodermal tumours; this lesion is, at times, described as angio-endothelioma.

Cavernous angioma

Port-wine stain

Racemose haemangioma

(5) Signs and symptoms

No pain

Except for the skeletal lesions angioma is quite painless. It causes little or no disturbance of function, except by its bulk. Unless infected or traumatized accidentally or by unsuitable treatment, it gives rise to no inconvenience and its unsightliness is the main reason calling for treatment. Diagnosis presents no difficulty and can be made at a glance on inspection of the tumour. The extent and character of the lesion are ascertained by the degree of blanching obtained on compression with a transparent glass or plastic spatula; by the

Diagnosis

filling and emptying of venous channels with posture-elevation of a limb or lowering of the head; by the colour of the lesion; by the character of the underlying tissue—firm or soft, lobulated or uniform; by the reduction in size on compression; by the presence or absence of pulsation.

4. PROGNOSIS

Progression in untreated lesions

Most types of tumour are progressive and if untreated will increase in size. The spontaneous disappearance of an angioma is exceptional, although it occurs in the "spider naevus" or other telangiectatic lesions of small dimension. Although progressive, the increase in size is irregular: very rapid during the first few months of life, a little slower during the first year, less so as time goes on. In adults, untreated lesions grow at various rates according to their morbid anatomical type.

Prognosis in treated lesions

Prognosis in treated lesions depends upon the type of tumour, the method of treatment and the skill and experience of the surgeon. Arrest of the disease may be accompanied by undesirable scarring and skin changes.

Early treatment

In haemangiomas, with the exception of the port-wine stain, it is important to appreciate that the earlier the treatment is given the better the cosmetic result and the simpler the treatment. Infants can be treated when but a few days old. In the case of the common strawberry mark every effort should be made to treat the lesion before the child is three months old.

In lymphangiomatous macroglossia and the diffuse type prognosis is poor. In all other types marked improvement or total disappearance of lesions can be achieved by suitable treatment.

5. CHOICE OF METHOD OF TREATMENT

Most important factors

Angiomas can be treated by surgical excision, radiation with radium or x-rays, injection of sclerosing solutions and freezing with solid carbon dioxide. The choice of the method depends upon the type of the lesion, its size and situation; upon the age of the patient and also upon the changes produced by previous treatment. Of these various factors the most important are the type and the situation of the angioma.

(1) Influence of type of lesion on choice of treatment

(a) Port-wine stain

Radiotherapy and radium unsuitable

This is unsuitable for radiotherapy; only slight alterations in the appearance of the lesion are obtained and the danger of necrosis is great. Port-wine stains should not be treated with radium. For cosmetic reasons, excision, grafting and, if necessary, subsequent tinting of the graft by tattooing should be done.

(b) Capillary haemangioma (strawberry mark)

Radiation suitable

This lesion is eminently suitable for radiation. Most experienced radiotherapists prefer radium to high-voltage x-ray radiation. Low-voltage x-ray radiation applied at very short distances from the skin, with very slight filtration, has given good results.

(c) Cavernous haemangioma

Sclerosing solutions

The treatment of this lesion depends primarily upon the site. In the skin and subcutaneous tissue, injection of sclerosing solutions is indicated in medium-sized lesions. In extensive lesions a combination of injection and radium

Radiotherapy and surgery

therapy (needles or seeds) is the method of choice. If the subcutaneous angioma is situated on the face or neck and extends into the pharynx or larynx, surgical excision of the subcutaneous tumour with ligation of the main afferent and efferent vessels is indicated, followed by radiation with teleradium or x-ray radiation to the visceral part of the lesion. Cavernous angioma of the lip and mouth should, in preference, be treated with interstitial radium.

(*d*) *Lymphangioma and compact haemangioma*

Surgery and post-operative radiation

These lesions are radio-resistant. Their treatment is mainly surgical. Post-operative radiation improves the results of surgery, it increases fibrosis and, by delaying recurrence, controls the spread of the tumour.

(2) Influence of site of lesion on choice of treatment

Radium therapy contra-indicated

The importance of the site of the lesion is chiefly in connexion with the damage caused to some tissues by radiation. Radium is contra-indicated in the following sites:

(a) Near the eye, as radiation is often followed by opacities of the lens.

(b) Near the epiphysis of long bones in young children, as retardation of growth of a limb may result, with consequent deformities of the hand or foot, or shortening of the limb.

(c) Near the testis, as the incidence of post-radiation atrophy is considerable.

(d) On the scalp, as epilation follows, and may be permanent.

(e) Near the midline over the area of the sternum, as in this situation unsightly keloid scars and radium necrosis are prone to occur.

The correlation of site of lesion and choice of treatment is shown in the Table.

Site of Lesion and Choice of Treatment

Site of lesion	First choice of treatment	Second choice of treatment
Muscle	Excision	—
Bone	High-voltage x-rays	—
Lips, mouth and tongue	Radium	Contact x-rays
Near eye	Excision	Sclerosing solutions
Near epiphysis	*Sclerosing solutions*	Radium
Scrotum	Excision	Radium
Vulva	Radium	Excision

(3) Influence of size of lesion on choice of treatment

Importance of early treatment

The smaller the lesion the better the result of treatment. Radio-sensitivity is very great during the first few months of life. It is therefore important to treat the lesions at an early stage. Infants up to six months of age respond very well to radiation treatment. In lesions on the face the cosmetic result of treatment is of importance, and the scars of radium are less noticeable than those of excision. On the trunk and limbs excision has many advantages, such as certainty of cure, speed of treatment and freedom from recurrence.

6. TECHNIQUE

(1) Surgical excision

(*a*) *Cutaneous lesions.*—Small cutaneous lesions can be excised with a scalpel or the diathermy needle. In either case the wound is sutured and primary

healing with a linear scar is obtained. In more extensive lesions, especially the port-wine stain and the capil ary haemangioma, suture of the wound is rarely possible; repair in such cases is done by means of skin grafts. Thin grafts (Thiersch) are unsuitable as the scar is unsightly; full-thickness grafts (Wolfe) provide a supple covering which, in the hands of an experienced plastic surgeon, gives an excellent cosmetic result. If skin grafting is undertaken, excision of the lesion should not be done by diathermy, and complete haemostasis should be achieved before applying the graft. The use of fibrin foam and thrombin as a local application to the raw surface achieves a bloodless area with the minimum of ligatures. The donor area is carefully chosen and should be devoid of hair; the graft is so cut as to fit accurately in shape and size to the raw area left by the excision. Perfect accuracy is obtained by using tin-foil or other pattern. The graft is stitched in position and pressure dressings are applied to minimize effusion of blood or serum, which otherwise would prevent adherence of the graft and so delay healing and spoil the cosmetic result.

Skin grafts

(*b*) *Subcutaneous cavernous haemangiomas and lymphangiomas.*—Surgical excision of subcutaneous cavernous haemangiomas and lymphangiomas can, in most cases, be achieved without any sacrifice of the overlying skin. Wide exposure is essential and the incision is so planned as to give good access to the entire lesion and its main afferent branches. All main vessels are carefully picked up, divided and tied. The tumour itself possesses an incomplete pseudocapsule, which is a help to the surgeon and acts as a guide to the depth to which excision should be carried out. Drainage of the wound in such cases is always indicated. Excision of lesions of the tongue should be carried out by diathermy. The current is so regulated as to cut slowly, produce haemostasis and yet leave only a thin layer of coagulated tissue at the periphery. No sutures should be used in the tongue or mouth, and the raw surface should be allowed to heal by granulation and centripetal extension of the mucous membrane. Even extensive resections carried out in this way heal in ten to fourteen days. With correct technique the post-operative course is smooth, rapid and painless.

Exposure and access

Procedure

(2) Radium therapy

Two methods of radium therapy are available: surface radiation and interstitial radiation.

(*a*) *Surface radiation*

This method is suitable for lesions of moderate extent; it is particularly suitable for the treatment of capillary angioma in young children. Both β-radiation and γ-radiation are used. For superficial lesions small monel metal or silver plaques containing 10 to 20 milligrams of radium are used. They are applied in contact with the lesion; the surrounding skin is protected by a thin layer of lead foil. The intensity of the plaque varies from 60 to 100 r per minute. An application of 45 to 60 minutes is given, and can be repeated three times at weekly intervals. In lesions of some thickness, say, 2 to 4 centimetres, silver or brass boxes containing platinum tubes are used. These boxes are placed at a distance of 2 to 3 centimetres from the skin; they carry 40 or 50 milligrams of radium, and have an intensity of approximately 20 to 40 r per minute at a depth of 1 centimetre from the surface. Three or four applications

Superficial lesions

Thick lesions

of two or three hours at weekly intervals are needed. The aim is to obtain a gradual regression of the tumour with the least skin changes.

(*b*) *Interstitial radiation*

Lesions in subcutaneous tissue and mouth

By this method radium is implanted into and deep to the lesion. It is suitable for cavernous angioma in the subcutaneous tissue and in the mouth. Gold or platinum seeds or radium needles are used. Each seed should contain 1 or 1·5 millicuries of radon: the length of the seeds varies from 1 to 3 centimetres; seeds *must* be removable and are provided with strings for that purpose. They are inserted by means of introducers of the trocar and cannula type. The seeds should be uniformly distributed throughout the volume of the tumour; the quantity of radon used and the number of seeds depend upon the bulk of tissue to be irradiated. The seeds are left *in situ* for 24 hours in young children, for 48 hours in adults. The dose should not exceed 2,000 r. In the mouth and tongue, especially in adults, radium needles are preferable to seeds as technically they are easier to introduce accurately. The insertion of seeds and needles causes only slight and momentary bleeding. Alteration in the lesion, its shrinkage, and diminution of the size of the individual vessels, can be noted as soon as one week after the treatment; the lesion continues to shrink for several weeks.

Distribution of seeds

Dosage

Results

(3) X-ray therapy

X-rays and radium compared

Both high-voltage and low-voltage x-rays are used in the treatment of angioma and it is claimed that x-rays are equally effective, yet most radiotherapists and dermatologists prefer radium, because of its greater ease of application, especially in young children. The use of low-voltage x-rays by the Chaoul or similar type of apparatus gives a possibility of using soft rays of very weak penetrating power and great intensity. At 90 or 100 kilovolts, 100 to 200 r per minute can be given to a depth of 1 centimetre. The treatment is very rapid: three to five minutes at a sitting; it is repeated at intervals of two or three weeks until a total of 1,500 to 2,000 r is reached. The subsequent course is similar to that after the application of radium.

Dosage

(4) Injection of sclerosing substances

Sodium morrhuate is the most favoured sclerosing solution; sodium salicylate and quinine–urethane have also their advocates. The injections should be given at weekly intervals; small quantities of solution only should be used, not exceeding 3 cubic centimetres. The technique is simple and consists in the insertion of a very fine hypodermic needle into the haemangioma. The injection is perivascular, and each cubic centimetre of solution injected will cause blanching in a radius of 0·8 centimetre around the needle. The needle is advanced deep into the tumour and small quantities of solution are distributed throughout.

Dosage

Technique

7. RESULTS OF TREATMENT

The results of treatment by surgical excision and radium in suitable cases are very good. Disappearance of the lesion with little scarring can be confidently anticipated. With contact low-voltage x-rays small lesions are also of good prognosis. Diffuse lymphangiomas are difficult to treat; diminution in size of the tumour can be achieved, but not entire regression, and the affected part

remains bulkier and prone to local infection and lymphostasis (*see* Fig. 106). The results of treatment in port-wine stains are disappointing unless excision and grafting are done.

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[References to other titles are given under Angioma in the Index Volume. The subject of Angioma is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 1, p. 577.]

ANTHRAX

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1. DEFINITION

32.] Anthrax is an acute specific infectious disease resulting from the growth of the *Bacillus anthracis* in the living tissues.

2. AETIOLOGY

Incidence

Primarily a disease of animals, anthrax affects especially the larger herbivora, such as cattle, sheep, horses and goats. The carnivora are but slightly susceptible. The disease is widely distributed throughout the world, but is influenced by climatic conditions and varies in frequency in different countries. It is prevalent in the warmer parts of France and Russia, in Egypt and South Africa, and especially throughout Central and Southern Asia.

Splenic fever

Spread among animals is by contaminated food. The bacillus, gaining entry through the intestinal mucosa, causes a rapidly fatal septicaemia, characterized by congestion of the intestines and lungs and enlargement of the spleen; hence the name, splenic fever.

Human infection

In man, anthrax is always secondary to the disease in animals and may be acquired either by direct contact with infected animals or their carcases or by handling animal products brought from countries in which the disease is rife.

Occupational

It is thus almost wholly confined to two sections of the community: the agricultural—farmers, veterinary surgeons, slaughterers, butchers—and the industrial—workers in hides, hair, wool, horn, upholstery, and in the porterage of these commodities between the docks and the factories. Infection unconnected with these occupations is exceedingly rare, but a few cases have

Accidental

been attributed to insect bites, and during World War I more than a hundred cases were traced to the use of shaving brushes imported from Japan.

3. BACTERIOLOGY

Bacillus anthracis is an encapsulated, non-motile, rod-shaped bacillus with square-cut ends, measuring 5 to 10μ in length. It stains well with ordinary

stains and is Gram-positive. It is aerobic, grows readily on the common media, and liquefies gelatin, giving an inverted fir-tree effect in a stab culture. In the living tissues the bacilli occur singly or in pairs, but in cultures long chains are formed.

Spores

Spore formation occurs in cultures, and in blood and excretions from infected animals when exposed to the air, but never in the living tissues. The spores are extremely resistant to drying and heat, retaining their vitality under suitable conditions in dust and surface soil for many years, and are the main agents in spreading infection.

4. MORBID ANATOMY

Mode of infection

Inoculation is commonly through an abrasion of the skin, or, possibly, sometimes through the unbroken skin via the hair follicles and cutaneous glands. More rarely the port of entry is the bronchial mucosa from aspiration of infected dust.

Local reaction

The immediate result is an acute inflammatory reaction characterized by intense tissue oedema, but with little or no migration of phagocytes to the part, and no suppuration. Local necrosis follows, with the formation of an eschar. The bacilli are at first localized, but after a variable interval, in unfavourable cases, they gain entry into the blood-stream, and the further course of the disease is that of a septicaemia. In mucous membrane infections the stage of eschar formation is rarely reached, because generalization of the infection occurs very early, and the course of the disease is extremely rapid.

General infection

Post-mortem

The post-mortem appearances are those of a virulent septicaemia with certain special features. These are lividity of the skin, gelatinous oedema of the loose tissues (especially the mediastinal and retroperitoneal), phlegmonous thickening of the walls of the stomach and intestines with multiple ulcers of their mucosa, and extravasations of blood beneath the serous and mucous membranes and sometimes in the meninges of the brain and spinal cord.

5. CLINICAL PICTURE

Clinical types

Two main types of anthrax occur in man, external or cutaneous (malignant pustule), and internal or pulmonary, known as wool-sorter's disease from its occupational association. A very rare gastro-intestinal form is also described.

(1) External (cutaneous) anthrax

Skin distribution

In almost every case the lesion is single and is situated on an exposed part. Legge (1934) gives the following distribution: head and face 44·6 per cent, neck 31·2 per cent, arm 20·4 per cent, leg 1·9 per cent, trunk 1·9 per cent. It is rare in women and children.

Incubation

The incubation period is commonly 24 to 48 hours, but varies from a few hours to 7 days.

The malignant pustule

A slight itching is the first sign of infection. A flat papule then forms, passing on to a vesicle which usually ruptures and dries up. About the third day surrounding oedema is observed and the characteristic appearances rapidly develop. These consist of a dark purple or black depressed eschar, surrounded by a raised circle of small vesicles containing straw-coloured fluid. Around this is a wide area of oedema and the regional lymph glands become enlarged and tender. (*See* Fig. 107.)

Enlargement

Oedema

The oedema is of a brawny consistence, and the skin over it may be hyperaemic, but it is not always so. The extent of the oedema is remarkable: with a lesion on the neck it may involve the whole face and spread far down on the trunk, and with one on the wrist the arm is likely to be swollen to the shoulder. In lesions of the neck a special danger is spread of the oedema to the glottis and mediastinum leading to dyspnoea and, possibly, suffocation.



FIG. 107.—Anthrax of forehead; oedema of face and neck. (*By courtesy of Dr. A. E. Hodgson.*)

Necrosis

The central area of necrosis is at first small, but later it may spread considerably. The necrosis is usually quite superficial, but in certain situations, in the eyelids, it may spread deeply and lead afterwards to a deforming scar. Suppuration never occurs and there is little pain apart from the discomfort due to tension. There is little or no leucocytosis. The constitutional symptoms up to this stage are not severe, and bear little relation to the size of the lesion or the extent of the oedema, unless the air passages are obstructed. There will probably be slight pyrexia, seldom above 101° F., and there may be headache and malaise, but there is, as a rule, surprisingly little evidence of toxaemia.

Constitutional symptoms

Further progress depends upon whether or not the blood-stream is invaded. This is likely to occur on the third or fourth day. If the disease remains localized the eschar becomes demarcated and separates after about ten days, leaving a granulating surface which slowly heals. The oedema subsides rapidly, though the glands may remain enlarged for some weeks. If, on the other hand, the infection becomes generalized (anthracaemia) the picture becomes one of a virulent septicaemia. Lassitude is marked and deterioration is rapid. Nausea and vomiting and sometimes diarrhoea occur from gastro-intestinal involvement, and cyanosis from pulmonary involvement; the temperature falls to below normal; the pulse becomes rapid, feeble and irregular, and death occurs suddenly from cardiac failure on about the fifth

Anthracaemia



FIG. 108.—Anthrax of chin; diffuse eruption and necrosis. (*By courtesy of Dr. A. E. Hodgson.*)

to the seventh day. The mind is usually clear to the end, but in some cases delirium, local palsies and coma, indicating cerebral involvement, precede death.

Variations Variations from the classical picture are not uncommon. The characteristic ring of vesicles may be absent and they may be distributed irregularly over a wide area (*see* Fig. 108), or a single vesicle on an oedematous ground may be the only visible sign. Again, the necrosis varies greatly in extent and may be absent altogether. The term, anthrax oedema, or erysipelatous anthrax, is applied to a rare form in which widespread oedema occurs with no obvious cutaneous lesion. This is usually on the face or neck and is fatal, since the stage of localization is very short. Death in such a case has been known to occur within twenty-four hours of inoculation. *Anthrax oedema*

(2) Internal (pulmonary) anthrax

The clinical aspect of pulmonary anthrax is quite indefinite in its opening phase. The patient simply feels ill, suggesting an attack of influenza. He may complain of oppressed breathing, and there may be blood-stained sputum in which the bacilli may be found, but the physical signs of disease in the lungs are meagre. The infection rapidly becomes generalized, and the later symptoms are those of the terminal stage of cutaneous anthrax. Death is almost inevitable and takes place generally within three days of the onset of symptoms. *Indefinite symptomatology* *Rapidly fatal*

6. AIDS TO DIAGNOSIS

The patient's occupation is nearly always strongly suggestive, and any unusual pimple in a man whose work exposes him to the risk of infection should at once be investigated bacteriologically. The bacilli are generally numerous in a smear taken from the exudate or from the vesicle fluid. In the early stage material for the smear may be obtained by excoriating the papule. Sometimes the bacilli are scanty and not easily found. In such cases recourse must be had to culture and animal inoculation. This takes time and, since delay is likely to prove disastrous, treatment should be started without waiting for bacteriological confirmation, if the clinical evidence of anthrax is strong. *Occupation* *Bacteriology*

7. DIFFERENTIAL DIAGNOSIS

The recognition of the fully developed malignant pustule is generally easy, provided that the possibility of anthrax occurs to the mind, and it is with the atypical and unexpected cases that mistakes are likely to be made. Diagnosis has to be made mainly from septic infections of the skin, more rarely from accidental vaccinia, extragenital chancre and glanders. With staphylococcal infections the pyrexia is more marked and there is pus formation with considerable pain; the oedema lacks the brawny induration of anthrax. Streptococcal cellulitis and erysipelas may simulate anthrax oedema, but the hyperaemia of the skin is more pronounced, and the temperature again is much higher than in anthrax. Both vaccinia and chancre, when occurring on the face, are apt to be accompanied by considerable oedema, and at first sight may closely resemble anthrax, but their development is slower and the subsequent course of the case will soon set any doubts at rest. Glanders, unlike anthrax, produces multiple lesions. It must be admitted that occasionally *Cutaneous sepsis* *Vaccinia and chancre* *Glanders*

anthrax is clinically indistinguishable from one or other of the conditions mentioned, and careful bacteriological investigation is the only means of reaching a diagnosis.

8. PROGNOSIS

Importance of early treatment

The prognosis of anthrax depends chiefly upon the stage at which diagnosis is made and treatment started. In untreated cases the mortality is over 50 per cent, but the severity of the disease varies greatly with its site, being far greater when the loose tissues of the neck and face are affected than when the lesion is on the limbs. Its severity varies also in different countries: in Africa and South America, for instance, anthrax runs a much milder course than is the rule elsewhere.

Variation in severity

Mortality in treated cases

If treatment is begun before the infection has become generalized a mortality of less than 5 per cent can be expected, and several series of cases without a death have been reported in recent years. When generalization has occurred the outlook is naturally far graver, but even then energetic treatment is often successful and there has been recovery in many cases which appeared hopeless when first seen. The patient's own estimate of his state is apt to be deceptive, and cannot be relied on as a prognostic indication.

Ominous signs

Ominous signs are a rapid feeble pulse with a falling temperature, dyspnoea and cyanosis, diarrhoea, vomiting and delirium.

Internal anthrax is almost invariably fatal, and so far no treatment has been found to affect its course.

9. TREATMENT

(1) Local

Rest essential

It is essential to keep the affected part immobilized—in the case of a limb by splinting, in that of the head or neck with sand-bags.

Dressings

Local applications have no curative value, and a simple antiseptic dressing is all that is needed, mainly as a precaution against infecting others. Whether the dressing should be wet or dry is a matter of individual opinion; I prefer to dust the lesion with sulphonamide powder and cover with a sterile pad.

Excision

The former custom *of excising the pustule* has now been universally condemned as unnecessary and, possibly, harmful, and has been superseded by the conservative measures in use today. These fall under two headings, serum therapy and drugs.

(2) Serum therapy

Anti-anthrax serum was introduced by Sclavo in 1899, with striking results. There are now several preparations of serum available, of which Sclavo's and Mulford's are the most widely used. Large doses are recommended: 100 to 250 cubic centimetres, according to the severity of the case, given intravenously and repeated daily until improvement is seen. This is usually within two or three days. Much larger doses have been advocated by some: Gold (1935) claimed that with an initial injection of 400 to 500 cubic centimetres, *repetition of the dose was rarely needed.*

Dosage

With novarsenobenzol

Serum seems to give better results when used in conjunction with the arsenicals, and this method has many advocates in England and America.

Hodgson (1941) reported a series of 93 cases, of which 52 patients received serum alone, with 6 deaths, and 41 serum and novarsenobenzol, without a death. He recommends the following regimen: first day, 100 to 250 cubic centimetres serum and 0·3 milligram novarsenobenzol; second day, serum alone; third day, serum and 0·45 milligram novarsenobenzol; fourth day, serum alone; fifth day, serum and 0·3 milligram novarsenobenzol. Mild cases required only one injection, very severe cases five or more. In severe cases he advises an extra injection twelve hours or less after the first.

(3) Drugs

The drugs now in use are the organic arsenical compounds, the sulphonamides and penicillin. Salvarsan has long been known to have a specific action on anthrax and holds an established position; the other two have been so recently introduced that the number of cases in which they have been employed is not yet sufficiently large for a clear estimate of their value to be formed. The results with both have, however, been so promising that either of them may well become the standard treatment of anthrax in the future.

Arsenicals

Novarsenobenzol, as already stated, has proved a valuable ancillary to serum therapy. If it is employed alone small doses are useless, and 0·6 to 0·9 milligram is recommended, injected into a vein daily or on alternate days. Not more than three injections should be given, or poisonous effects may follow. This method has never found much favour in Great Britain, where the risk of toxic effects has, perhaps, been exaggerated, and most surgeons have advised it only as a substitute for serum when this is not available; but in South Africa and elsewhere one or other of the arsenicals has been used as a routine for anthrax for many years with success. Pijper (1926) treated 40 cases with novarsenobenzol, without a death, using an initial dose of 0·9 milligram, which was repeated on the second day and again on the fourth, if it was needed.

Sulphonamides

Treatment with the sulphonamides and with penicillin has been given very successfully in recent years, but the opportunities for their use have been comparatively few, especially in the case of penicillin. Of the sulphonamides, sulphapyridine was shown by Cruickshank (1939) and others to have a controlling effect on anthrax in mice. Sulphathiazole appears to be nearly as effective clinically, and it has the advantage of not causing nausea. Gold (1942) reported a series of 60 cases, of which the first 20 were treated with serum, with one death, and the remaining 40 with sulphathiazole, with no deaths. He gave an initial dose of 3 to 4 grammes followed by doses of 1 to 1·5 grammes every four hours. Three of his patients failed to respond to sulphathiazole and received serum as well. Comparing the results of the two methods, he found that the average length of stay in hospital and total absence from work were 15 and 37 days respectively with serum treatment, and 8 and 15 days with sulphathiazole.

The sulphonamides have the merit of being always readily obtainable.

Penicillin

B. anthracis was listed by Fleming (1929) among the bacteria whose growth in culture was inhibited by penicillin, and significant evidence of its effect on anthrax in mice was produced by Heilman and Herrell (1944). The number of occasions on which it has been given clinically for anthrax is still very small,

but rapid recovery has been reported in every case. Dosage has been at the rate of 100,000 units *per diem*, given by continuous intravenous instillation.

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ANUS, ARTIFICIAL (MANAGEMENT)

By LIONEL E. C. NORBURY, O.B.E., F.R.C.S.
Senior Surgeon, Royal Free Hospital; Senior Surgeon, St. Mark's Hospital, London

1. GENERAL

33.] It is a good plan before subjecting a patient to a colostomy or artificial anus, if he is apprehensive as to his future mode of life, to ask someone who has had the experience of an artificial anus for some years to talk to the patient and explain from his personal knowledge that it is possible in such circumstances to live as a useful member of the community. I have often found that after such a conversation and encouragement, a previously reluctant patient will alter his mind and undergo the operation without further misgiving. Again, in the early days of colostomy life, sympathetic encouragement and advice, given by an old operation case, will do more than any written instructions to help in the correct management of an artificial anus.

Encouragement and advice

The hospital patient with a colostomy is placed at a great disadvantage in that very few convalescent institutions will admit this class of case. One looks forward to the day when convalescent institutions, especially those connected with special hospitals for rectal diseases and diseases of the colon, will be established, so that a patient with an artificial anus can have some weeks' training in his new mode of life, and thus acquire confidence by undergoing a course of both mental and physical rehabilitation.

Many patients with an artificial anus lead active lives; they play tennis and golf, dance, swim, dig in the garden and ride bicycles.

Activity

(1) Varieties of artificial anus

There are two situations usually employed for the fashioning of an artificial anus, corresponding to a left iliac and a transverse colostomy. The management of these is identical in all essential respects.

Situations

With an artificial anus established in the transverse colon, the motions tend to be more fluid and less easy to control than with a left iliac colostomy, but this, as a rule, is only a temporary embarrassment, and by careful attention to diet and exercise is soon overcome.

Main varieties

There are two main varieties of artificial anus: (a) a terminal colostomy (*see* Fig. 109); (b) a colostomy in continuity, or loop colostomy (*see* Figs. 110 and 111). In the latter variety, there are two openings, one being the active stoma

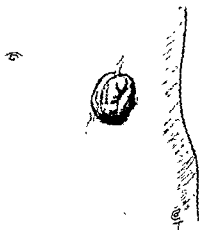


FIG. 109.—Terminal colostomy.

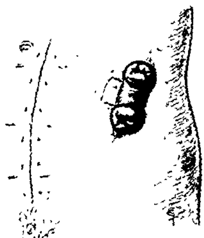


FIG. 110.—Colostomy in continuity (loop).

and the other non-active. With this variety, management includes attention to both stomas. This is considered in more detail below.

(*a*) *Essential factors in establishment of a well-functioning colostomy*

(i) There should be a good spur.

(ii) The bowel should not protrude excessively.

(iii) The artificial anus should not be too tight.

Complications

A terminal colostomy seldom has complications if reasonable care is taken in its construction. With a loop colostomy, however, a good spur is essential in order to prevent faeces passing from the upper or acting end into the distal stoma.



FIG. 111.—Left iliac colostomy; skin bridge and division of bowel.

(*b*) *Complications*

(i) *Prolapse.*—This may occur at either the proximal or the distal end of a loop colostomy, but usually at the former. (*See* Fig. 112.) In the case of a left iliac colostomy, it can be prevented to a great extent by operative technique so that no slack bowel is allowed to be present above the stoma.

Intussusception

I have seen a retrograde intussusception of pelvic colon through the lower stoma (*see* Fig. 113); the affected bowel became gangrenous.

(ii) *Stenosis of the skin.*—In relation to the artificial anus, stenosis of the skin is not uncommon, and may be prevented to some degree by removal of a circle

of skin at the time of operation. With stenosis of the skin orifice, the gut may remain pouting through and become obstructed and oedematous. Such a condition may be associated with a hernia. *Hernia*

A patient with an artificial anus should be examined every few months to see that the colostomy is functioning satisfactorily, and to avoid complications *Examination*



FIG. 112.—Prolapse of both ends of left iliac colostomy.



FIG. 113.—Retrograde intussusception and prolapse of lower end of colostomy (finger placed in upper acting end).

such as retraction of spur, prolapse, stenosis and hernia. Reconstruction of the colostomy may be necessary for retraction of spur and for stenosis. *Reconstruction*

2. MANAGEMENT

At first a patient with an artificial anus is liable to have occasional accidents from mismanagement or from indiscretions of diet, but after a few weeks confidence is obtained and unexpected actions of the bowel seldom occur, except perhaps as the result of carelessness. With a recently formed colostomy patience and practice are required to learn how best to manage the artificial anus, but after such knowledge has been acquired little inconvenience should be experienced.

(1) Methods employed to obtain regular bowel action

There are two methods employed in order to obtain satisfactory action of the bowels:

(a) The daily wash-out method.

(b) The method of allowing the bowel to act naturally, relying on careful attention to diet and regulated exercises.

(*a*) *Daily wash-out*

The wash-out is given each morning at the same hour after breakfast. The technique is as follows. A soft rubber colostomy catheter, size 15, is well lubricated and gently inserted into the acting stoma for about two-thirds of its length. If there is any difficulty in insertion, no force must be employed but patience must be exercised. Sometimes peristalsis is active, and spasmodic contraction of the bowel may temporarily inhibit the passage of the tube. *Technique*

A douche can fitted with rubber tubing and containing two pints of warm water, normal saline solution, or soapy water, is connected by a glass connexion to the catheter. The fluid is run in slowly and is returned into a

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Fig. 109.—Terminal colostomy.

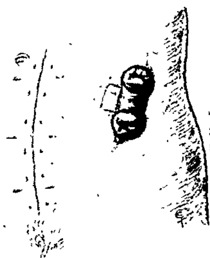


Fig. 110.—Colostomy in continuity (loop).

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FIG. 112.—Prolapse of both ends of left iliac colostomy.



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A douche can fitted with rubber tubing and containing two pints of warm water, normal saline solution, or soapy water, is connected by a glass connexion to the catheter. The fluid is run in slowly and is returned into a

kidney dish or basin. A Higginson's syringe may be used instead of the douche can. To prevent leakage, a horn, such as that devised by Nitch, may be fixed in position over the colostomy by means of a strap; the returning fluid is conducted into a receptacle.

Leakage

Retention of fluid

Sometimes a portion of the wash-out fluid may be retained and subsequently passed just as the toilet of the colostomy has been completed. It is usually possible for the patient to determine by his own abdominal sensations whether any fluid has been retained, and to spend a little extra time over his toilet in consequence.

Objections

One of the chief objections to the wash-out method is that the colon tends to become irritable after irrigations have been carried out over a number of years. Spasm of the colon results and there may be excessive secretion of mucus. This is not so liable to occur if plain water or saline solution is employed instead of soapy water.

Advantages

The great advantage of the wash-out method is that, after a perfectly conducted irrigation, there should be no further action of the bowels until after the next wash-out on the following morning, provided that there is no indiscretion of diet. Patients employing this method have been known to discard the colostomy belt provided, and to wear a small pad of wool over the artificial anus, kept in position by a piece of tape or a strap.

There is no doubt that the wash-out method is an excellent one provided that the necessary time can be given. Some thirty to forty minutes are required each morning for completion of the toilet.

Perforation of bowel

Disadvantages.—Besides the time required for a satisfactory wash-out, there is a real disadvantage, and that is the danger of perforation of the bowel by the injudicious passage of the tube. If force is employed when inserting the tube, or if a too rigid tube is employed, the bowel may be perforated. The lesion may involve the colon as it passes through the thickness of the abdominal wall in a patient who is obese, when extensive cellulitis may follow; or the perforation may be intraperitoneal, a complication fraught with serious consequences. In subjects with diverticulosis of the colon, there is a risk that the tube may be stopped in its passage by a diverticulum, which may be perforated. A small number of such cases has been recorded, and I myself have seen examples of both intraperitoneal and extraperitoneal perforation.

(b) Allowing natural action of bowel

The other method of routine management is to allow the artificial anus to act naturally and without wash-outs. Subjects who have been in the habit of having a daily action of the bowels soon after breakfast will find that, with careful attention to diet, such regularity can be maintained. To start with, the diet should be of non-roughage consistency. Experience will show that certain articles of diet may cause loose and irregular colostomy actions. These can be found only by trial and should then be avoided. It is impossible to give a list of such articles, since people differ in their reaction to diet. For instance, I had a patient who invariably had a loose colostomy action after drinking a glass of beer, but not if he drank stout. Onions in any shape or form seem to act adversely. Aperients should be avoided as a rule. If there is constipation, small doses of liquid paraffin may produce a satisfactory action. Prunes or stewed apples taken with the evening meal may be effective. A teaspoonful of I-so-gel granules taken at night will produce a bulky colostomy stool in the

Diet

Constipation

morning. The ideal colostomy stool should be formed and not loose. Regularity of action is obtained after a few weeks' probation. A natural action occurs after breakfast, the motion being allowed to pass into a loose dressing or into a kidney dish. A further action may occur about tea-time.

Regularity

(2) Management of lower colostomy opening

With a loop colostomy performed for an inoperable growth or for some other form of obstruction, such as diverticulitis or simple stricture, it is advisable for a wash-out of the distal colon to be given through the lower stoma, in order to prevent accumulation of mucous and other discharges. This should

Wash-out of distal colon

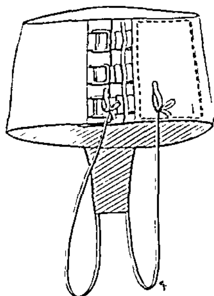


Fig. 114.—Abdominal belt.

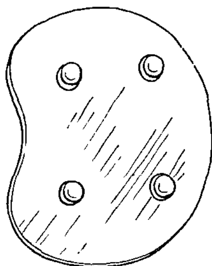


Fig. 115.—Celluloid supporting plate.

be done once or twice a week, using either saline solution or weak solution of Dettol or some similar antiseptic.

(*a*) *Belts*

There are many forms of belts employed in the management of the artificial anus. The simpler the belt the better. Abdominal support is advisable after an artificial anus has been established, since there is always a weakness in the neighbourhood of the colostomy. The belt should be made of fabric, and the inner aspect of the portion which covers the colostomy should be lined by some water-proof material. The type of belt which is chiefly employed at St. Mark's Hospital, London, is illustrated (*see* Fig. 114). By means of the broad portion and fulcrum band, it is possible to give firm support to the lower abdomen. A celluloid plate is usually applied over the colostomy, separated from it by a layer of cellulose tissue. The plate is kept in position by projecting studs which are gripped by the overlying belt. (*See* Fig. 115.) The plate serves *to give extra support; it is not, however, essential. It is* inadvisable to use any form of cup or bag, since, as the result of the suction effect on the abdominal wall, there is a great liability to produce herniation. No collecting receptacle should be necessary with an artificial anus which is properly attended to.

Material

Celluloid plate

Cup or bag inadvisable

Home-made belt

It is not uncommon for a patient with an artificial anus to wear a home-made abdominal belt of the simplest variety as a means of keeping the dressings in position and, at the same time, giving some degree of support.

Night dressing

At night, a dressing of cellulose tissue is applied to the artificial anus and kept in position by a simple woollen body-belt, which can be washed, or by a broad crêpe bandage or a many-tailed bandage.

(*b*) *Dressings*

Care of skin

After a morning colostomy action, as a result of either natural methods or a wash-out, the skin around the artificial anus is washed with soap and water, and some talcum powder applied. One should be careful in the use of ointments or greasy material, since these are liable to soil the belt and weaken its texture. Many different forms of dressing are employed in the management of an artificial anus, but a simple routine is as follows: A piece of gauze is placed over the colostomy and then the celluloid plate is applied. A flat piece of cellulose tissue with a hole in it is placed over the plate, and then another piece of the same tissue, but without a hole, is applied over this and secured by the belt. The pieces of cellulose tissue should be about eight inches square.

Simple routine

Cellulose tissue

Cellulose tissue has a great advantage over cotton-wool, since it can be thrown down the drain, whereas cotton-wool must be burnt because it blocks the drain.

Baths

A patient with an artificial anus can have baths in the ordinary way without any cover for the artificial opening.

[References to other titles are given under Anus, Artificial (Management) in the Index Volume.]

ANXIETY STATES

By SIR CHARLES SYMONDS, K.B.E., C.B., D.M., F.R.C.P.
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1. DEFINITION

34.] Anxiety is the psychological term used for a state of tension or unpleasant excitement akin to fear. Anxiety state is used by psychiatrists as a diagnosis to cover psychological illness characterized especially by morbid anxiety. The essential qualification for this is that the anxiety be in excess of that which the observer would judge a "normal" person to be feeling under the circumstances. This article will be confined to the discussion of anxiety states in relation to surgical practice.

2. AETIOLOGY

Inheritance

Familial experiences

There is evidence which strongly suggests that the disposition to morbid anxiety may be inherited. Independently of this, the experiences of childhood and adolescence, and especially the personal relationships formed during this period, may determine an anxious constitution. Anxiety in the parents, lack of parental encouragement and affection, emotional over-dependence on the parents, social and economic insecurity in the home, are features often to be found in the background of these cases. Illness or disaster in the family during childhood may have special significance. Habits of anxiety may also be formed as the result of stress experienced in

4. DIAGNOSIS

In circumstances in which anxiety is natural, the distinction between a normal and a morbid state is arbitrary and must be guided by the experience gained by doctor and nurse of other individuals in like situations. Irrational fear may be said to be the criterion of morbid anxiety, but fears which appear irrational to those who work in the atmosphere of the sick-room may be entertained by normal persons, who at the same time are often free from apprehensions which the observer with greater knowledge of the facts would think reasonable. The diagnosis must be made by weighing the symptoms already described in relation to the individual situation.

Criterion of morbid anxiety

5. PROGNOSIS

One of the characteristic features of morbid anxiety is its tendency to persist in spite of reassurance, and even after the immediate causes have been removed. The patient who has had a successful operation finds fresh food for anxiety in thoughts of complications, delayed convalescence, what may be going wrong at his work in his absence, whether he will be as fit for his work as before, and so on. In fact, the anxiety state, however generated, tends to acquire a momentum of its own. The prognosis depends mainly upon its duration and the way in which it is treated. Chronic anxiety states which have existed for months or years usually have their roots in an abnormal constitution, and the prognosis for full recovery is bad. It must be remembered that such cases are not very uncommon, and that the chronic neurotic is no less susceptible to surgical disease than others. Anxiety is sometimes wrongly assumed to be a reaction to surgical illness when it is really symptomatic of a pre-existing chronic anxiety state, and an optimistic prognosis is given. Patients with more acute and shorter-lived anxiety states, if properly treated, will nearly always recover. What effect surgical treatment will have on the prognosis will depend upon how far the anxiety is a reaction to this aspect of the situation. An anxiety state centred upon the possibility of a malignant growth will be relieved by a favourable verdict, though it may yet be some time before it is dissipated.

Duration and treatment of morbid anxiety

Effect of surgical treatment

6. TREATMENT

(1) Establishment of relationship with patient

In treating an anxiety state, the surgeon must be ready to listen to the patient's complaints, and this is specially desirable at the first interview. He may well need to proceed first to the inquiries which are necessary for a proper appreciation of the physical state, but should then invite the patient to volunteer any further information which he thinks may be important. He must be prepared to encourage confidences and to answer questions which seem unnecessary or irrelevant. Outlines of the personal history and present situation are essential to the proper understanding of the illness. The patient's account of himself should be supplemented whenever possible by information obtained separately from a relative. It is useless to undervalue the symptoms of an anxiety state or to create the impression that the patient is giving way to his fears. Such an attitude is likely to provoke resentment and do harm. The

Encourage confidences

psychological distress and its bodily accompaniments are real and must be accepted as such. In the discussion and explanation of the patient's fears, distinction should be made between those which are natural and experienced by everybody in the same situation and those which are unjustifiable or excessive. The latter should be explained as symptomatic of the psychological or nervous disorder in the same way as pain is a symptom of bodily illness. The patient should be assured that a nervous illness of this kind is of common occurrence in persons of a certain constitution and that with proper treatment he will get well. The special factors in the situation should be discussed with understanding, sympathy and encouragement. If the patient is moved from his home into a hospital or nursing home, it is of value to prepare his new environment beforehand by introducing books, photographs or other personal belongings which will give him a sense of familiarity and comfort. The selection of his visitors is a matter of importance, and must be guided by their capacity for adding to his feeling of security. Before and after an operation the presence of a dependable relative is desirable.

Natural and excessive fear

New environment

Visitors

(2) Explanation of malady to patient

The problem of explaining to the patient the nature, causes and treatment of his malady needs careful management. It is important that before each new step he should be told enough to satisfy his reason, and that he should be forewarned of pain. When an anaesthetic is given, the method of preparation and induction should be such as is calculated to cause least apprehension.

Relief of apprehension

(3) Management of pain

Pain is badly tolerated by these patients and the mistake is often made of giving too little post-operative morphine. The dread of pain in a case of this kind cannot be treated successfully by a demand for fortitude which is beyond the patient's capacity. There is some danger of morphine addiction because opiates relieve not only physical pain but mental tension. Therefore, whenever the local condition indicates that pain should be tolerable, morphine should be withdrawn and other analgesics and sedatives given if necessary.

Morphine

Of the sedative drugs, chloral hydrate is one of the most useful in a dose of up to 10 grains for an adult, thrice daily after food. Small doses of barbiturates, for example 2½ grains of Medinal (soluble barbitone; Barbital Sodium, *U.S.P.* XII) thrice daily, are an alternative, but should not be given if a barbiturate is used as a hypnotic. Bromides are of little value in small doses, and in large amounts are apt to cause toxic symptoms, including restlessness and confusion. They are therefore best avoided. The control of sleep presents a difficult problem. Anxiety may be focused on insomnia in a patient who is, in fact, obtaining an adequate amount of sleep, so that observation is necessary before it is decided that hypnotics should be given. If there is true insomnia, there should be no hesitation in giving an adequate dose of one of the barbiturates. Nembutal (soluble pentobarbitone; Pentobarbital Sodium, *U.S.P.* XII), in a dose of 1½ to 3 grains, acts quickly and has relatively little toxic after-effect.

Sedatives

Hypnotics

(4) Post-operative occupation

The post-operative occupation should, as far as possible, be planned beforehand. Times should be allowed for some kind of constructive occupation

Constructive occupation

suitable to the habits and inclination of the patient. Bead or leather work should be provided for those who have no alternatives. Serious or semi-serious reading and visits from friends should be included in the programme, and light reading saved for the latter part of the day. Pleasant food and an appropriate ration of alcohol and tobacco are of as much psychological importance in the care of the patient with an anxiety state as of others.

Diversions

(5) *Continuity of advice and treatment*

Finally, it is of the utmost importance that there should be continuity of advice and treatment when the patient passes from one doctor to another—for example, when he leaves hospital to return to his home under the care of his own general practitioner. Personal consultation at this stage is the ideal, but when this is impossible, written advice to the doctor should precede his first attendance on the patient so that there is no break in the atmosphere of security.

Consultation with patient's doctor

(6) Psychiatry

The advice given in this article is applicable to anxiety states which can be managed by the surgeon and general practitioner. If psychological disorder is apparent but the diagnosis is in doubt, or if there are problems of prognosis or treatment which demand more expert advice, the co-operation of a psychiatrist will naturally be sought.

[References to other titles are given under Anxiety States in the Index Volume.]

APPENDICITIS, ACUTE

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1. AETIOLOGY

Age

Race

Diet

35.] Acute appendicitis, the commonest acute abdominal disease, may occur at any time from birth to old age although much more frequently between the tenth and thirtieth years and rather more often in males than in females. Its greater incidence amongst Anglo-Saxons is accounted for by the fact that the diet of these peoples contains a greater proportion of protein and less cellulose as compared with other diets, with corresponding effects on bowel action. A higher rate of incidence in certain families is also probably due to similar habits and diet rather than to any real familial tendency.

2. ANATOMY AND PHYSIOLOGY

(1) Peritoneal fossas

Three fossas are commonly present: (1) caecal or retro-caecal, beneath and behind the free end of the caecum; (2) superior ileo-caecal, bounded by the vascular fold of the caecum, just above the termination of the ileum; (3) inferior ileo-caecal, bounded by the bloodless fold of the caecum (Treves). This fold is inconstant and is often distended with fat; sometimes it contains

blood-vessels and may be a nuisance when invaginating the stump of the appendix; on the other hand it may be useful in covering a bare area. The appendix may be trapped in any of the three fossas.

(2) Dimensions, position and direction

Length and thickness

Variability of position

The length of the appendix varies from three-quarters of an inch to eight or nine inches and the thickness from one-eighth of an inch to five-eighths of an inch. The position may vary widely, depending upon congenital or acquired peritoneal relations of the caecum. In the great majority of cases it is situated in or near the right iliac fossa, and if a point is taken two inches medial to the anterior superior spine of the ilium on a line drawn from the latter to the umbilicus, it will usually be over its root. If the caecum fails to descend during the rotation of the gut on the superior mesenteric artery, the appendix may be found at any point between the liver and the right iliac fossa. In other cases with excessive descent the appendix is carried deep into the pelvis or over to the left side of the abdomen. In relation to the caecum the appendix may be attached more or less by congenital or acquired peritoneal folds or adhesions when it may be embedded in the caecal wall, the posterior abdominal wall or one of the various fossas; alternatively it may be relatively free to pivot in any direction on its root, when it may point in one of many directions which for all practical purposes may be reduced to five, as follows: (1) into the iliac fossa, (2) over the pelvic brim, (3) behind or lateral to the caecum, (4) behind the mesentery of the ileum, (5) in front of the caecum or ileum. The symptoms, signs, complications, diagnosis and treatment of any case are naturally influenced by the specific position taken by the appendix. (*See* p. 297.)

Relation to the caecum

(3) Function

Nothing is known of any special function performed by the appendix. It does secrete mucus, which is passed into the caecum by peristalsis; if appendicular obstruction is present, the lumen may be distended by mucus. There is also absorption of water, and if this is carried to excess there is inspissation of the contents and formation of faecoliths and concretions. On x-ray examination, if the appendix fills and empties with the caecum, it is considered to be normal; non-filling and retention of the barium sulphate (sometimes for weeks) or tenderness on palpation are pathological signs.

3. BACTERIOLOGY

Organisms concerned

Mode of infection

Streptococci, *Bacillus coli communis* and *B. aerogenes capsulatus* are the most important organisms concerned. Direct bacteriological evidence of the part played by each is difficult to obtain, but clinical observation suggests that the initial infection is probably caused by streptococci and the appendix may continue to be so affected unless obstruction is present, when the infection is rapidly overborne by growth of *B. coli* and anaerobes. Infection probably enters by the mucous surface as it does in other mucous membranes. The presence of lymphoid tissue and the concurrence of appendicitis and tonsillitis suggests that a blood-stream infection exists in some cases. Any condition leading to excessive peristalsis or stasis in the appendix predisposes to infection. The part played by mechanical factors has certainly been exaggerated, about 75

Obstruction

per cent of cases not showing any sign of obstruction of the lumen. Obstruction may arise from outside, by congenital peritoneal folds or kinks, or from the inside, by concretions formed of cellular debris and inspissated mucus. Acquired external adhesions or kinks and internal scars or stenosis may predispose to recurrent attacks, but obviously these cannot account for a first attack.

4. MORBID ANATOMY

Wilkie's classification

The credit for recognizing two primary and fundamentally different acute conditions of the appendix is due to Wilkie (1914, 1931), who gave the following classification:

(1) Acute inflammation of the wall—acute appendicitis;

(2) Acute obstruction of the lumen—closed loop intestinal obstruction.

Type (1) may be referred to as non-obstructive, type (2) as obstructive.

(1) Non-obstructive type

Changes in wall of appendix

In the non-obstructive type the wall shows changes corresponding to the degree of infection present, ranging from those of a mild catarrh of the mucous membrane to those of an acute suppurative inflammation of all the coats, passing on to ulceration or even to gangrene.

(2) Obstructive type

Faecolith

Kinks and fibrous strictures

Gangrene and perforation

In the obstructive type a faecolith is responsible for the obstruction in the great majority of cases although a kink or a fibrous stricture may have a similar effect. The portion of the appendix distal to the obstruction, being exposed to the tension within the lumen and affected by interference with its blood supply by the pressure of the concretion and the stretching of the walls, soon becomes gangrenous. The danger of perforation or rupture is particularly great owing to the greatly increased numbers and virulence of the organisms incubated in the closed lumen.

5. CLINICAL PICTURE

Course

The disease begins as one or other of the two pathological types, non-obstructive or obstructive, the ratio being about 3 : 1. Either condition may resolve or progress and give rise to various complications, three of which are unfortunately so common as to be regarded as further clinical types. In their order of frequency they are localized peritonitis, localized abscess and diffuse peritonitis.

Clinical features

In any particular case the clinical features depend primarily upon three main factors—the presence or absence of obstruction, the position and direction of the appendix, and the stage of the disease at which the patient is first seen.

(1) Appendix in iliac fossa

(a) Non-obstructive type

Classical signs

About 75 per cent of cases fall in this group. If the appendix is in the right iliac fossa, the symptoms and signs usually follow the classical order emphasized by Murphy (1889), namely, fairly sudden generalized abdominal pain, accompanied by nausea and vomiting and followed by pain in the right side, with localized tenderness and rigidity in the right iliac fossa and, after the first twenty-four hours or so, signs of toxic absorption.

lumborum or the psoas muscle, with pain on extension of the thigh. Abscess is a common sequel.

(*c*) *Post-ileal* (*mesenteric*)

The appendix being buried behind or within a bunch of coils of the ileum, localization of the pain is indefinite. There is a fullness of the lower abdomen with some tenderness, not necessarily very acute, and a tendency to early intestinal obstruction. Here also abscess is a common sequel.

(*d*) *Pre-ileal* (*abdominal wall*)

Local signs

This is the most obvious of all the various types; the appendix is adherent to the anterior abdominal wall and the local signs are plain. Tenderness and rigidity are emphasized and hyperaesthesia is more common than in any other type; the thighs are often flexed in order that the abdominal muscles may be relaxed. Later, as the disease progresses, a definite lump can be seen, especially on viewing the abdomen tangentially, and in some cases there is oedema of the tissues over it.

Swelling and oedema visible

(3) Complications

(*a*) *Localized peritonitis*

Spread of infection

Localized peritonitis follows either of the primary types, and is not usually established until the second or third day; it implies either a perforation or spread of the infection through the wall. The initial colicky pain may have continued or subsided. The local spread of the infection causes a continuous aching or boring pain, intensified by movement or pressure. It is accompanied by an increase in the area of tenderness which is earlier and more constant than the rigidity which ensues, and by a rise of temperature of a few degrees.

Localized infection

Sooner or later the spread is arrested and the infection remains localized according to the position of the appendix, the two commonest sites being the pelvis and the right flank.

(*b*) *Localized abscess*

The distinctive sign of an abscess is a tender fixed swelling, rarely appearing within forty-eight hours and usually on about the third or fourth day, in one or other of the typical or atypical situations of the appendix and supervening on the signs of inflammation.

Pelvic abscess

A pelvic abscess commonly gives rise to urinary or to bowel symptoms. Frequency and pain on micturition, or at the end of the penis, are the result of irritation of the ureters or the bladder; tenesmus, with mucus in the stools, arises from inflammation of the rectum. In women the pelvic organs are involved; leucorrhoea, or less commonly menorrhagia, may be present. The pathognomonic sign is the presence of an acutely inflammatory mass filling the recto-vesical or recto-uterine pouch, with little or nothing palpable above the pubis.

Retrocaecal abscess

A retrocaecal abscess may be ill-defined and "silent" at first owing to the fact that it is overlaid by the caecum, but sooner or later a tender inflammatory mass develops in the loin.

Post-ileal or mesenteric abscess

A post-ileal or mesenteric abscess also develops insidiously from an acutely inflamed appendix lying behind and amongst coils of ileum. In this case owing to the overlying coils of gut, frequently distended from partial obstruction, the abscess is not easy to feel and remains ill-defined. In spite of the distension, tenderness and rigidity are easily elicited.

A pre-ileal abscess resembles the common iliac abscess in its course but the signs are more definite, the mass is better defined, hyperaesthesia is often a prominent feature, the tenderness and rigidity are extreme and oedema of the abdominal wall occurs fairly early.

Pre-ileal abscess

(*c*) *Diffuse peritonitis*

This may supervene on any of the above, gradually or with sudden pain and collapse if perforation of a distended appendix or rupture of an abscess occurs. Sudden increase in abdominal pain, rising pulse rate and widespread tenderness are very suggestive and are confirmed later by the usual rigidity and distension. Ileus is a common sequel.

Danger of ileus

6. DIAGNOSIS

The history, signs and symptoms will, if carefully assessed in the light of the surgical anatomy and pathology, usually enable the surgeon to arrive at a diagnosis not only of appendicitis but also of the position of the appendix and its pathological condition. In a fair proportion of cases the order of the symptoms may be atypical, and vomiting or a rigor, the latter especially in children, may precede the pain. In others, perforation may occur so rapidly that the signs of peptic ulcer are simulated.

7. DIFFERENTIAL DIAGNOSIS

(1) Conditions giving rise to pain with tenderness or rigidity

(*a*) *Early pneumonia*

Diagnosis may be very difficult; the sites of pain and rigidity are higher than usual; careful palpation shows that there is no real deep localized tenderness, and as a rule the increased respiratory rate and the occurrence of an occasional grunt call attention to the chest.

Pulmonary signs

(*b*) *Leaking duodenal ulcer*

A leaking duodenal ulcer, with the duodenal contents trickling down the mesentery or paracolic gutter to the right iliac fossa, may simulate appendicitis. In the absence of a history of the typical sudden onset of the pain associated with collapse, the signs may indeed be indistinguishable from those of appendicitis. At operation it is noted that there is excessive exudate which may be bile-stained, and the inflammation of the appendix affects the peritoneal coat rather than the whole wall.

Similarity of signs and symptoms

(*c*) *Acute cholecystitis*

In this case, the onset is more abrupt and the pain may radiate to shoulder or back; tenderness and rigidity are at a higher level although the whole of the right side of the abdomen may be affected; the enlarged gall-bladder may be felt, and if so it will be found to move with respiration; vomiting is more persistent; the temperature is higher, 103° F.; there may also be rigors.

Tenderness and rigidity at higher level

(*d*) *Ureteral calculus*

Apart from typical renal colic there may be a dull aching pain with tenderness in the right iliac fossa but usually no rigidity; the urine may contain erythrocytes and pus in either condition if the appendix is adherent to the ureter; x-ray examination and cystoscopy should help if time permits; in urgent cases it is safer to operate.

X-ray examination and cystoscopy

(*e*) *Acute pyelitis*

Renal signs

The kidney may be enlarged and tender; abdominal rigidity is indefinite; the temperature is usually higher and accompanied by chills; dysuria is more in evidence and the pain begins in the side.

(*f*) *Pneumococcal peritonitis*

Secondary infection

Pneumococcal peritonitis usually occurs in young girls, either secondary to pneumonia or to otitis, and therefore less likely to cause difficulty, or primarily as an ascending infection from the vulva. When the vulva is the source, the condition usually appears as an acute peritonitis without any definite localization, although as it is initially a pelvic infection it may cause diarrhoea. As a rule the temperature is high, 103° F. or more, and vomiting may be severe. A vaginal discharge is present in practically every case and the organisms can be found in it. Although the right treatment is generally considered to be conservative, it is easy to make the mistake of not operating in a case of pelvic appendicitis in a little girl, and it is therefore wiser to operate.

Diarrhoea and vomiting

Vaginal discharge

(*g*) *Acute salpingitis*

Comparatively speaking the patient is less ill; the history is often vague and may be misleading; headache is common; tenderness is often bilateral or greater on the left side and in the lower abdomen; there may be leucorrhoea and dysuria, but this does not exclude appendicitis (*see* pelvic abscess above); per rectum (better than per vaginam) the swellings characteristic of the inflamed tubes may be felt.

Importance of rectal examination

(*h*) *Ruptured ectopic gestation*

Gynaecological signs

The signs of internal haemorrhage may be prominent; if not, the slight bleeding from the uterus, invariably present, the softening of the cervix and the moderate enlargement of the uterus clinch the diagnosis.

(*i*) *Ileo-caecal lymphadenitis*

In children this may resemble closely an acute or subacute attack of appendicitis. The acute cases cannot be differentiated. In the subacute cases the points of resemblance are pain localized to the right iliac fossa, generalized tenderness on pressure, slight rise of temperature and occasionally vomiting. The important differences are the absence of the initial midline pain and the muscle rigidity later. It is always wiser to operate if in doubt.

Absence of early midline pain

(*j*) *Regional ileitis* (*Crohn's disease*)

Although regional ileitis is more commonly chronic or subacute in its course, a number of cases in children are on record in which ileitis has been indistinguishable from acute appendicitis. At operation the congested and thickened lower ileum, and the masses of glands in the mesentery, are in strong contrast to the normal appendix.

(2) Colicky abdominal pain without rigidity

This may be due to the following conditions:

(*a*) *Intestinal colic*

(*b*) *Appendicular colic*

Character of the attack

This is characterized by sudden attacks of colicky or stabbing abdominal pain, referred to the umbilical region or vaguely to the right side of the abdomen; these attacks vary in intensity but have no relation to food; they are often accompanied by headache, nausea or vomiting. The attacks end suddenly and the patient is comparatively well until the next attack occurs.

Examination of the abdomen immediately after an attack discloses nothing abnormal, although there may be slight tenderness over the appendix without any rigidity. The pathology is that of a true colic without inflammation and is usually due to the temporary impaction of a concretion or a foreign body. If this is not extruded into the caecum and the block becomes complete the condition may change into that of the acute obstructive type of appendicitis.

(*c*) *Obstructive appendicitis in its early stages*

(*d*) *Biliary colic*

The onset is usually more abrupt and severe; the pain may radiate to the back or shoulders and may be relieved by pressure; there is often a history of many previous attacks with flatulence, indigestion and possibly jaundice; the pulse rate and temperature are not raised and there may be some degree of shock.

Nature of pain

(*e*) *Renal colic*

If typical, this is unmistakable (*see* ureteral calculus above).

(3) Conditions likely to be mistaken for acute appendix abscess

Acute appendix abscess may be simulated by the following:

(*a*) *Twisted ovarian cyst*

In this condition the swelling can be palpated bimanually and is mobile; the onset of the pain is abrupt and is often associated with shock.

(*b*) *Iliac lymphadenitis*

A primary focus may still be present but the lesion is often healed by the time the patient is seen or there may have been a preceding inguinal adenitis; psoas spasm may be present in either condition.

(4) Subacute or unresolved appendix abscess

The condition of inflammatory mass, or "infiltration", when seen some weeks after the commencement of the attack resembles the following:

(*a*) *Hyperplastic ileo-caecal tuberculosis*
(*b*) *Regional ileitis (Crohn's disease)*
(*c*) *Actinomycosis of appendix or caecum*
(*d*) *Carcinoma caeci*

Whereas a long history excludes appendicitis and is in favour of actinomycosis, tuberculosis, ileitis or carcinoma in that order, a short history is of little value by itself since any of these conditions are liable to be complicated by a sudden acute infective process. The younger the patient the more likely is it that the case is one of appendicitis or ileitis. The swelling tends to become fixed early in appendicitis and ileitis, late in the other three diseases; its consistence in ileitis may be hard and nodular; its lower border may be well defined in tuberculosis, shading off above into the colon. Signs of obstruction appear earliest in ileitis, and x-ray examination may show a filling defect proximal to the caecum, dilatation of the lower ileum and Kantor's "string" sign, an irregular line running through the filling defect. In many of the above the diagnosis can be made only on exploration.

Kantor's "string" sign

(5) Important factors in differential diagnosis

(a) Acute appendicitis remains the commonest acute abdominal condition and many of the above are relatively infrequent.

Frequency

(b) The greatest difficulty will be found in conditions giving rise to pain

Exclusion of pneumonia

with tenderness or rigidity. Particular care should be taken to exclude conditions such as pneumonia in which operation is contra-indicated.

Double infection

(c) In rare instances more than one condition may be present, for example pneumonia and acute appendicitis.

8. INDICATIONS FOR SURGICAL INTERVENTION

As there are considerable differences of opinion and some degree of confusion in the literature with regard to the indications for operation in certain cases, and in order also to simplify the discussion, the various types of cases already described may be regrouped as follows:

(1) Early (one to three days)

Unperforated

(a) Non-obstructive
(b) Obstructive

Perforated

(a) Local peritonitis
(b) Diffuse peritonitis

(2) Late (third day onwards)

(a) Localized peritonitis
(b) Abscess
(c) Inflammatory mass
(d) Diffuse peritonitis
  (i) Failure to localize
  (ii) Secondary to rupture of an abscess

Factors in the decision regarding operation

The following factors have also an important bearing upon the decision to operate: doubtful diagnosis, extremes of age, pregnancy, bad risks.

No one questions the advisability of immediate operation in the early group, in cases of diffuse peritonitis secondary to rupture of an abscess, and in childhood, old age or pregnancy. Equally no one doubts the necessity for extreme care in weighing the chances of operation in cases of bad operative risk. In the remainder of the late group, the usual practice is to operate on all patients as soon as the diagnosis is made, unless it is obvious that the disease is already subsiding.

(3) Rationale of surgical intervention

(a) The Ochsner treatment

Unfortunately in spite of their frequency many cases have already reached the late stage before the patients are seen by the surgeon and in consequence the general mortality has been higher. For years it it has been urged that many of the deaths are really due to untimely or injudicious operating, and there has been a reaction led by Ochsner (1902) in the United States of America in favour of conservative treatment in all cases, except those of children, seen forty-eight hours or more after the onset.

The Ochsner or expectant treatment is based on the assumption that after the first forty-eight hours adhesions will have formed which should not be disturbed by operation, or alternatively that the patient is in a negative phase so far as the infection is concerned. Treatment is therefore directed towards

allowing the peritonitis to become localized and subside, appendicectomy being performed two or three months later (Ochsner, 1921). The original Ochsner treatment consisted of rest in bed in the Fowler position, the avoidance of purgatives or purgative enemas, prohibition of all food or drink by the mouth, lavage of the stomach to relieve nausea or pain (one-sixth of a grain of morphine is given if lavage is necessary), nutrient enemas of one ounce of pre-digested food in three fluid ounces of saline solution every four hours. The method has been followed and modified by many surgeons, particularly in Great Britain by Sherren (1905, 1925), Love (1923, 1924, 1929) and Bailey (1940). Owing to the danger inherent in the method that the infection may not subside, it is emphasized that it can be carried out only in an efficiently equipped hospital or nursing home by a thoroughly trained and capable diagnostician who must keep the patient under continuous observation and must be prepared to operate at a moment's notice if the treatment fails.

Original treatment

Modifications

Essentials of successful treatment

As a routine for all cases after the first forty-eight hours the Ochsner method is open to the serious criticisms mentioned below.

(i) The rigid time limit of forty-eight hours for the inception of the treatment is based on faulty appreciation of the pathology—in some cases the appendix may still be unperforated.

(ii) The published figures supporting the assumption of the dangerous period and the so-called negative phase are not free from fallacies.

(iii) *Mistakes in diagnosis have resulted in other conditions being subjected* to the method, with fatal results.

(iv) When the treatment fails the mortality is admittedly greater and complications are more common and more serious.

(v) If the disease does subside, the patient has to face an operation which may be difficult, and also a further period of absence from work.

(vi) Owing to the stringent limitations imposed the method is quite impracticable for many surgeons and in many localities.

(b) The question of immediate operation

On the other hand, surgeons who practise immediate operation claim that it is impossible to predict the course of any particular case, that immediate operation is generally applicable except in very extraordinary circumstances, that the diagnosis is thereby confirmed or not and appropriate treatment instituted at the earliest possible moment, and that there is then no need for any further prolongation of the anxious observation of the patient.

Factors favouring immediate operation

The results of immediate operation in localized peritonitis or frank abscess are so good that only patients suffering from some intercurrent affection increasing the operative risk provide justification for the delayed method.

Good prognosis

The inflammatory mass, or "infiltration", doubtless subsides and disappears in many cases under expectant treatment; in others the inflammatory residues remain unabsorbed for weeks. In carrying out the expectant method in the earlier stage the difficulty of accurate diagnosis has to be contended with; later there is the danger of secondary rupture of an abscess, a risk which has often been underestimated. For these reasons it may be safer to operate, provided that the type is recognized at operation and that extensive manipulations are not attempted in the search for the appendix.

Further good reasons for operating

(c) The danger of toxaemia

Between third and sixth days

Toxaemia dominates the picture when the peritonitis fails to become localized and it is particularly serious in patients first seen between the third and the sixth day after the onset. The first co-ordinated treatment of such cases was that of Murphy (1909), who held that the cause of the infection (in this case the appendix) should be removed, and with the least possible trauma; he was also of the opinion that there should be adequate drainage of the peritoneal cavity, maintenance of the Fowler position, inhibition of peristalsis by withholding all fluid or food by the mouth and the continuous administration of salines per rectum by means of a special nozzle and reservoir which permitted the escape of gas.

Murphy's principles

Mortality

Although the results have been greatly improved, the general mortality of immediate operation in cases of diffuse peritonitis remains very high. It is said to be considerably less when expectant treatment is established, but it is obviously difficult to make any true comparison owing to the uncertainty of the extent and virulence of the infection in any given case. A certain number of cases must be written off in any series, since the patients are moribund when first seen.

By deferring operation for a few hours or days in order to permit treatment to counteract the effects of toxaemia and dehydration, some surgeons claim to have more than halved the mortality, and it is probably along these lines that improvements in the results will come. Even so such cases bristle with difficulties and many other points are still in dispute. Some argue that the appendix, being the source of the continued infection, must be removed and that drainage alone is useless; others hold that drainage relieves tension and therefore diminishes the rate of absorption and has the advantage of being easily provided under local anaesthesia, thus avoiding the added risk of a general anaesthetic. Others again rather arbitrarily consider that absorption of toxin from the wound in immediate operation is greater than the absorption from the peritoneal cavity when operation is deferred.

In general, the indications for or against operation in any particular case must remain a question of individual experience and judgment unbiased by any set rules of treatment.

9. PRE-OPERATIVE MANAGEMENT OF THE PATIENT

(1) Operation postponed or avoided

Essentials of expectant treatment

If it is decided for various reasons that it is advisable to avoid or postpone operation, expectant treatment may be given a trial. The essentials are the adoption of the Fowler position, so long as the exudate is not localized, the keeping of a close watch by chart on the pulse rate and the physical signs (the temperature not being quite so important), the giving of fluid per rectum or intravenously and the forbidding of fluid or food by the mouth for four days or more. If progress is satisfactory, small feeds of Benger's food and similar preparations may be given, these being gradually increased. When the infection is subsiding pain is slight and can be relieved by the hot-water bottle; if the pain becomes worse it denotes failure of the method; the giving of morphine is avoided for that reason. After feeding is begun a small glycerol enema may be given, but purgatives of any kind should not be prescribed

until the pulse and temperature have been normal for a week and abdominal signs are absent, that is to say resolution has occurred; small doses of liquid paraffin may then be given.

Increasing pain, a rising pulse rate, vomiting or diarrhoea are all danger signals and indications that the treatment has failed. *Danger signals*

(2) Cases of ileus

Patients with diffuse peritonitis and with extreme toxaemia and dehydration are greatly improved by preliminary treatment for some hours and particularly if there are signs of ileus. This fatal complication may arise in two ways: (a) as a widespread inflammation of the wall of the small intestine due to diffuse peritonitis; (b) as a result of local involvement of a loop, kinked or twisted, in close relation to an abscess, usually in the pelvis. The former, a true adynamic (paralytic) ileus, is characterized by absence of colicky pains or signs of peristalsis, audible or visible; the latter, although it may simulate the former and indeed eventually may become identical with it owing to spread of infection, is essentially an obstruction and is usually at first accompanied by definite peristalsis and by signs of an abscess in the pelvis. *Causes of ileus*

The general pre-operative treatment of both conditions is the same. The dehydration and loss of chlorides is made good by a continuous intravenous infusion of saline and glucose (normal saline 1 part, 5 per cent glucose 4 parts); suction through a retained duodenal tube or a Miller-Abbott tube relieves distension and vomiting. The giving of concentrated oxygen (90 to 95 per cent) by a B.L.B. mask helps to diminish distension by replacing unabsorbable nitrogen and possibly inhibits growth of anaerobes in the intestines. Warmth applied to the abdomen by means of hot blankets and hot-water bottles or by radiant heat or electric cages relieves shock and pain. Enemas and peristaltic stimulants are contra-indicated. *Pre-operative treatment*

As soon as the patient's condition is sufficiently improved, operation should be undertaken. Operation should not be delayed too long, however, if it is probable from the signs that the ileus is of the localized type. The earlier the operation the greater the likelihood that the loop can be freed. *Decision to operate*

10. OPERATIVE TECHNIQUE

(1) The incision

Of various suggested incisions, four are commonly used in different types of cases, these being known as McBurney's, Battle's, the paramedian and Rutherford Morison's. McBurney's incision is the most generally useful and apparently much the most popular.

(a) *McBurney's incision*

McBurney's split muscle, or so-called gridiron, incision is three inches or more in length according to the amount of fat present in the line of the fibres of the external oblique muscle, and is made one and a half to two inches from the right anterior superior spine, the upper third of the incision lying above and at right angles to the spino-umbilical line. Some surgeons prefer a direction rather more towards the horizontal, which brings the incision into line with the skin creases. In any case if the appendix can be felt when the patient is anaesthetized, the incision can be made directly over it. The external *Length and position* *Variations*

oblique muscle is split in the line of its fibres and the edges are drawn apart with retractors, exposing the internal oblique muscle and the outer edge of the rectus sheath on the medial side of the wound. The sheath is now opened by cutting it transversely for about half an inch from its outer edge (Weir's modification) and continuing the incision through the linea semi-lunaris outwards and splitting the fibres of the internal oblique and the transversus

Weir's modification

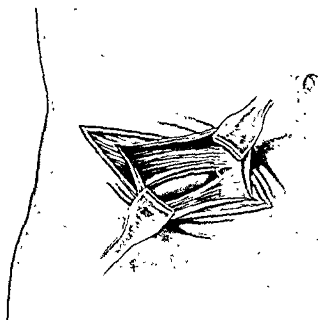


Fig. 117.—McBurney's incision, modified by splitting the rectus sheath (*Weir*).

muscles (*see* Fig. 117). In doing this, an inconstant vein may be encountered running along within the outer angle of the sheath, and this should be ligated if present, otherwise it may cause a haematoma. Care should be taken not to open the peritoneum now; it is best opened after retracting the edges of the internal oblique and the transversus muscles.

Ligature of vein

Peritoneum

In cases of difficulty better access can be obtained in two ways as follows: (i) The incision may be converted into a modified Battle's incision by

Alternative methods

continuing the opening in the rectus sheath vertically downwards for two or three inches (*see* Fig. 118), in which case nerves may be injured; (ii) as preferred by the writer, the rectus may be retracted firmly and the incision

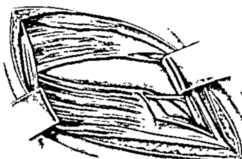


FIG. 118.—McBurney's incision. Conversion to modified Battle incision.

extended at either end parallel to the nerves, the rectus sheath at the inner end and the whole thickness of the muscles at the outer end being cut through as required (*see* Fig. 119). The McBurney incision with the above modifi-

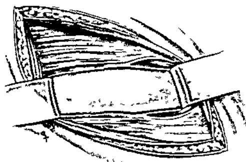


FIG. 119.—McBurney's incision—still further enlarged medially by splitting the rectus sheath and retracting the muscle.

cations will be found adequate in all the uncomplicated and in most of the complicated cases.

(*b*) *Battle's incision*

An incision about four inches long is made vertically with its centre midway between the anterior superior spine and the umbilicus; the rectus sheath is

opened one inch from the outer border and the muscle is retracted inwards. Originally the posterior layer of the sheath and the peritoneum were incised vertically, care being taken to avoid nerves and the inferior epigastric vessels; alternatively the incision in the posterior layer of the sheath may be made transversely as described above. One of the advantages claimed for the incision is the possibility of exploration in a doubtful case. This actually is extremely unsatisfactory because of risk to nerves, and most surgeons would probably prefer a paramedian incision. Other disadvantages are its greater distance from the usual site of the appendix and its unsuitability in the event of drainage being required owing to the risk of hernia or of haemorrhage from the inferior epigastric vessels.

Advantages and disadvantages

(*c*) *The paramedian incision*

This runs parallel to the middle line and from half an inch to one inch to the right of it and opens the rectus sheath in the same line, the muscle being retracted outwards and the posterior layer of the sheath and the peritoneum being incised together in the original line. It possesses the inestimable advantage of being capable of extension from one end of the abdomen to the other with less risk of hernia in most cases than has any other incision.

Possibility of extension

For the vast majority of cases of acute appendicitis it is quite unnecessary; the operation takes longer because of the necessity for dissecting up the anterior layer of the sheath of the rectus, a proceeding often accompanied by much bleeding from small vessels; it may be too far from the site of the appendix for adequate exposure except through a long incision, and for the same reason is unsuitable for a drainage tube.

(*d*) *The Rutherford Morison incision*

In localized abscesses

The Rutherford Morison incision is useful for localized abscesses, especially if the latter are adherent to the anterior abdominal wall or in the flank. It is made over the swelling in the line of the fibres of the external oblique muscle; the internal oblique and transversus muscles and peritoneum are all cut in the same line. Since this incision lies parallel to the nerves it can be extended without harm outwards or inwards if necessary, although in the latter event the inferior epigastric vessels must be ligated. If the nerves are preserved and the muscle layers are carefully sutured by interrupted sutures the risk of post-operative hernia is slight except in cases complicated by gross infection. (*See* Figs. 120, 121, 122.)

(2) Digital exploration

Freeing of caecum or appendix

The caecum usually presents in the wound and a finger is gently inserted to ascertain the position and the type of appendix. In many cases the caecum and appendix are free and can be brought out of the wound without difficulty, a proceeding which does not do any harm and which very much facilitates removal of the appendix. If the caecum or appendix is fixed by recent adhesions, one or the other or both may as a rule be easily separated by gentle stripping with the finger; alternatively the appendix may be delivered wrapped in the end of the omentum. Rarely the appendix may not be felt at all, in which event the caecum should be hooked up by passing the finger beneath one of the taeniae coli, which should be followed down to the root of the appendix. The presence or absence of adhesions and the type of adhesions if present, whether they be of recent inflammatory type or possibly represented by congenital

Adhesions

folds, constitutes the chief difficulty of the operation. In dealing with them experience is undoubtedly the best guide. Until experience is gained the operator should bear in mind that nothing is more likely to cause serious complications than rough handling or ruthless stripping up of dense peritoneal folds or adhesions and that in all cases of difficulty the incision must be enlarged so that he can see what he is doing.

(3) Gauze packing

Before the peritoneum is opened the edges of the wound should be protected by mackintosh pads, and to prevent further infection of the peritoneal cavity,

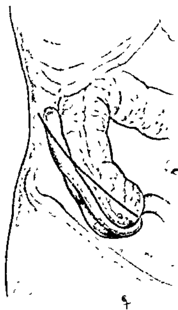


FIG. 120.—The Rutherford Morison oblique incision, parallel to the nerves, and cutting all muscular coats. The incision is shown longer than would be necessary, but indicates the possibility of extending it in either direction as required.

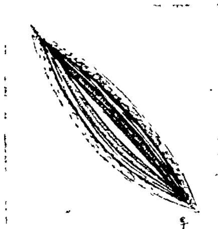


FIG. 121.—Showing the various muscular layers of the abdominal wall incised to expose the peritoneum.

in every case in which pus may be present either in the lumen of the appendix or in an abscess, the area of operation should always be surrounded by gauze packs wrung out in normal saline. In the case of very large abscesses some form of suction apparatus, if available, may be very useful.

Prevention of peritoneal infection

(4) Removal of the appendix

In some cases, owing to the presence of adhesions, it may be impossible, without using undue force, to free the tip of the appendix. The so-called retrograde method is then available. The root of the appendix is crushed by two pairs of artery forceps and cut between them, the cut surfaces being swabbed with iodine (*see* Fig. 123). The stump is held out of the way by the

Retrograde method

forceps on it and the meso-appendix is clamped and cut, the surgeon gradually approaching and removing the tip with as little injury to other structures as possible. The stump is then invaginated as usual (*see* below *and* Fig. 124). Rarely it may be impossible to free the appendix at all, the whole process being embedded in the caecal wall. An incision is then made along it down to the submucous coat and the whole of the submucous and mucous coats are shelled out, the tube of mucous membrane ligated at the root and

Embedded appendix

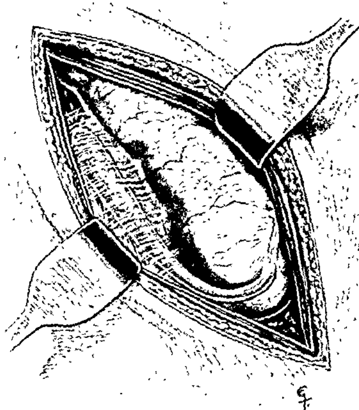


Fig. 122.—The Rutherford Morison incision; adherent appendix, lateral to the caecum, fully exposed.

cut away, the stump and the resulting gutter being swabbed with iodine solution. It is better not to suture the walls; they should be left open and drainage should be provided.

(5) Treatment of the stump

Many different methods have been devised, most of which are unnecessarily complicated. The method of crushing the base of the appendix, ligating it and invaginating the stump into the caecum by a simple purse-string suture

Invagination

or Moynihan's letter "N" stitch remains the simplest and most satisfactory. Simple invagination may be impossible when the caecum is very indurated. It may then be necessary to cut the root off flush with the caecum and to suture the opening in two layers, reinforcing the serous layer with whatever is handy—meso-appendix, fat or omentum—the essentials being the closure

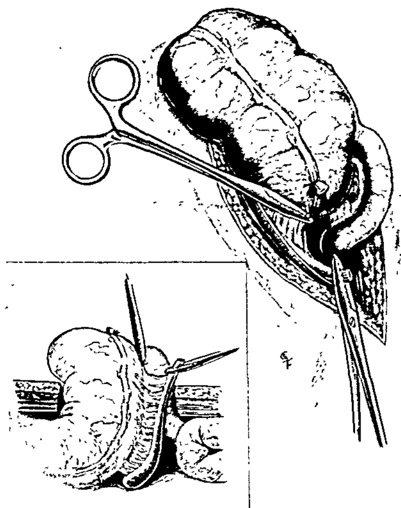


FIG. 123.—Removal of appendix, retrograde method. The root of the appendix has been crushed and divided between forceps. The inset shows the lateral view.

of the hole and the establishing of haemostasis. Objection is raised to the invagination method in that it forms a small abscess in the wall of the caecum. There is no general evidence of this or of any harm if this should occur, besides it has been found by most surgeons to be simple and effective. Other less simple methods which require swabbing with phenol or the turning down of a peritoneal cuff are quite unnecessary.

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Embedded appendix

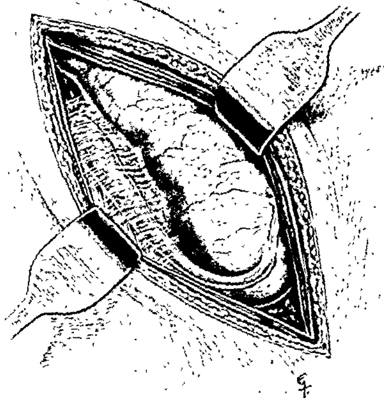


FIG. 122.—The Rutherford Morison incision; adherent appendix, lateral to the caecum, fully exposed.

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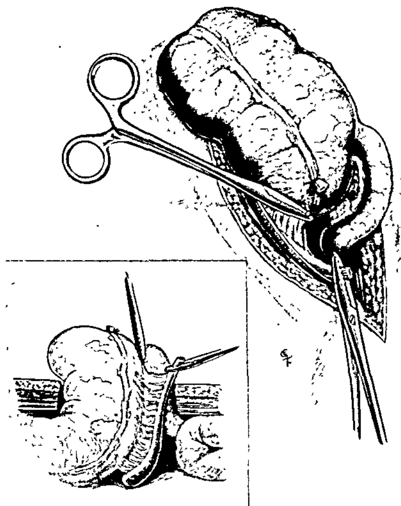


FIG. 123.—Removal of appendix, retrograde method. The root of the appendix has been crushed and divided between forceps. The inset shows the lateral view.

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(6) Drainage

Cases not requiring drainage

Although the tendency of late has been to drain much less often it is still a safe rule to drain when in doubt. Drainage is required practically never in early cases in which infection is still confined to the appendix; in many

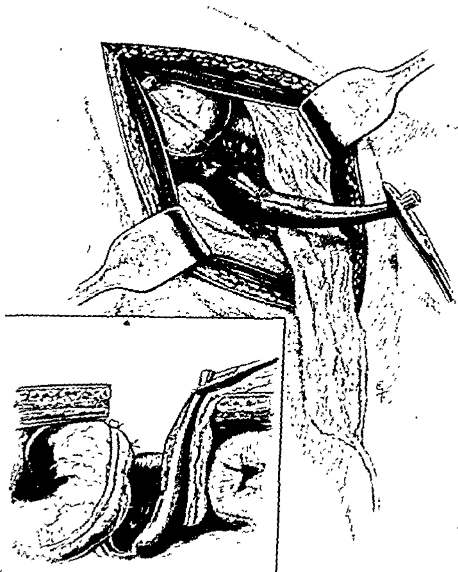


FIG. 124.—Removal of appendix, retrograde method, meso-appendix divided gradually and ligated. The inset shows the lateral view.

cases of suppurative inflammation with involvement of the peritoneal coat and localized peritonitis the patients also do well without drainage. Most cases of abscess, cases of peritonitis with much effusion in the flank or pelvis and cases in which there is persistent haemorrhagic oozing are safer with a drain. Attempts to determine for or against by bacteriological examination are unfortunately not practicable. The writer's views may be summarized as

Cases requiring drainage

Summary

follows: The drainage hole should be regarded as a safety-valve rather than as a conduit; it is a guarantee that if pus collects it will not do so under pressure with its consequent increased absorption. It is often said that pus will not drain uphill and therefore it is useless to put a tube into the pelvis from a McBurney or a suprapubic wound. This is to think in terms of gravity only; the intra-abdominal pressure may be a much more potent force in acute cases. This does not set at naught the rule which states that drainage at the lowest point is best in chronic cases. The drainage material should be soft, smooth and non-irritating. Rubber tubing, split along its length, or rubber dam best satisfies these requirements. Gauze wicks or packs tend to become choked with blood or pus and to act as corks rather than as valves and they may become adherent to the gut. Stiff tubes with lateral holes in them may cause ulceration of the gut or vessels or may entrap gut or omentum in the holes. The tubing should be shortened daily but not completely removed. This prevents too long or too great pressure in the depths of the wound and re-infection from the edges of the wound as the tube is being replaced, an event much more common than is generally realized. The criteria for final removal are the quantity and character of the discharge and the condition of the patient. In most acute cases the discharge lessens rapidly and a drain is seldom required for longer than two or three days. In chronic cases the drain may be partly responsible for some of the discharge and it may be a matter of better placing of the tube, as noted above.

Drainage material

Daily shortening of tube

Final removal

(7) Haemorrhage

Serious results may be seen if haemorrhage is not properly controlled, infected blood clot being one cause of residual abscess. In some cases a persistent oozing occurs from the appendix bed after adhesions have been separated. So long as the caecum is kept prolapsed out of the wound it is difficult or impossible to expose the bleeding area. A useful manoeuvre then is to push the caecum back into the abdomen and up towards the liver, thus exposing the whole field (*see* Figs. 125, 126). A suture may be much safer and quicker in action than a ligature in these circumstances; moreover, a haematoma in the wall of the gut or mesentery which is not spreading may be ignored; otherwise very careful suturing is necessary to avoid puncturing other vessels hidden by the fat.

Suturing

(8) Abscess

If possible, abscesses should not be opened across the peritoneal cavity. The chief exception is the mesenteric abscess, surrounded by coils of ileum and not in contact with the abdominal wall at any point. Careful packing-off is necessary in these cases. In all others an extraperitoneal approach should be made if possible. If the peritoneal cavity is opened in the original incision and it is apparent that an extraperitoneal approach can be made, there should be no hesitation in closing it and in making another at a more suitable place, in the flank or groin. A low pelvic abscess is best opened from the rectum; the vaginal route is messy and the drainage is not so good. The rectum and bladder should be emptied; the anterior wall of the rectum is exposed through a proctoscope and if the abscess is pointing it is easily opened with a pair of curved dissecting scissors or sinus forceps; if not, it may be necessary to explore first with a wide-bore needle and then to incise along the track; a drainage tube is inserted and cut off just outside the anus, to which it is

New peritoneal outlet

Technique

secured by a stitch (*see* Fig. 127). In about 85 per cent of abscesses the appendix can be removed without much difficulty; if this proves impossible it should

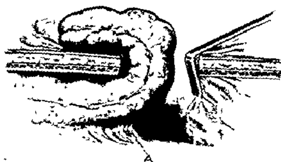


FIG. 125.—Control of haemorrhage. A. Haemorrhage hidden by gut.

be removed three or four months later when the infection has subsided with drainage.



FIG. 126.—Control of haemorrhage. Caecum pushed into abdomen, exposing bleeding point.

11. POST-OPERATIVE CARE AND COMPLICATIONS

(1) Uncomplicated cases

These require little if any after-treatment, and unless the operative procedure has had to be modified on account of obesity or other circumstances, the patients are encouraged to get up much earlier than formerly; in the average case the bed period is only about six days.

Apart from the complications discussed later, many patients do suffer from a mild degree of peritonitis. In these the Fowler position is maintained so long as it is probable that the exudate is free to drain into the pelvis; once it is localized it is useless to enforce the position at the expense of rest and sleep unless it aids respiration. The giving of sips of water usually does no harm

Mild perito

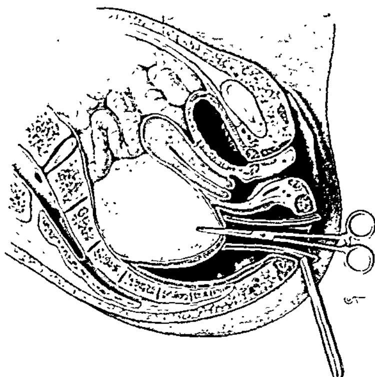


FIG. 127.—Opening of pelvic abscess from the rectum. The anterior wall of the rectum is exposed through a speculum, and the sinus forceps is shown penetrating through the abscess wall.

and greatly increases the comfort of the patient. As a rule rectal or intravenous salines are not required. If there is much nausea or vomiting as a result of the anaesthetic a long drink of water containing sodium bicarbonate, 60 grains per pint, usually proves an effective lavage. Sedatives are scarcely needed after the first night, when one-sixth of a grain of morphine may be given. Abdominal distension, exclusive of ileus, is commonly due to gas in the colon and is greatly relieved by a small turpentine enema or intramuscular injections of acetylcholine. Passage of a flatus tube may give relief, but it sometimes fails. The bowels usually act naturally in two or three days and from this time can be kept open by liquid paraffin and an occasional enema. Drainage tubes are shortened and removed as soon as possible.

During the past two or three years several writers have reported benefit from the action of the sulphonamide group of drugs in suppurative appendicitis.

Sulph amide

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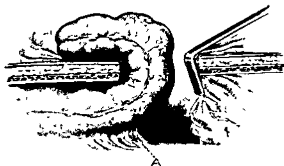


FIG. 125.—Control of haemorrhage. A. Haemorrhage hidden by gut.

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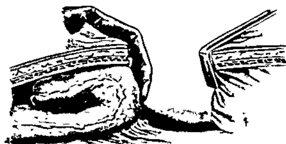


FIG. 126.—Control of haemorrhage. Caecum pushed into abdomen, exposing bleeding point.

11. POST-OPERATIVE CARE AND COMPLICATIONS

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analgesia is clearly indicated so that the affected coil may thus be freed, often a simple procedure as the adhesions are only recent. If this cannot be done an enterostomy as near the obstruction as possible may relieve it.

Operation with spinal analgesia

(c) *Suppurative pylephlebitis*

This fortunately is rare and is to be suspected in a case presenting rigors with a swinging temperature; or it may develop as an acute, subacute or chronic post-operative complication. It is said to be more likely to supervene in cases in which there has been gangrene of the appendix. Examination may reveal some tenderness and enlargement of the liver and possibly an icteric tinge of the conjunctivae. Once abscesses have developed in the liver the prognosis is usually fatal, although certain patients have recovered after drainage of the abscesses. In some apparently genuine cases patients have recovered without operation. Ligature of the ileo-colic vein has been successfully performed by Taylor in an early case; this was reported by Stewart-Wallace in 1935.

Rigors and swinging temperature

Icterus

(d) *Suppuration in the wound*

Suppuration in the wound is very rare in cases in which perforation has not taken place. In late cases in which drainage has been established a certain degree of infection in the wound is to be expected, although even in these it is rare for it to show any signs of spreading unless the patient's general condition is bad; it is typical of poorly nourished children. In these circumstances cases have been reported of extensive cellulitis and gangrene of the abdominal wall with fatal results. Protection of the wound edges during the operation and free drainage and antiseptic dressings all help to prevent or to minimize the infection. It is in these cases that the local application of sulphonamides should prove useful.

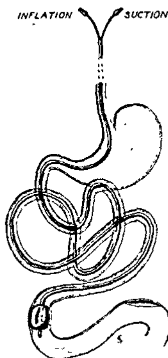


FIG. 128.—Diagram to show the Miller-Abbott tube *in situ*.

(e) *Residual abscesses*

When residual abscesses develop a week or so after operation they give rise to symptoms corresponding to their situation. The Fowler position accounts for a pelvic abscess being the most common. The only point to stress here is the necessity in case of doubt to exclude it by a rectal examination.

Pelvic abscess

A subphrenic abscess is more likely to follow a retrocaecal appendicitis. Suspicion of such a condition should arise if after the first week the tongue is

Subphrenic abscess

Although there is no indication for their use in unperforated cases or as an alternative to operation, they might be very useful in cases showing signs of toxaemia or septicaemia. The evidence in favour of various antitoxic serums for this or other complications such as ileus is very poor.

(2) Complications

As pointed out long ago by Murphy, the two chief causes of complications are delay in operating and overdoing it later. In most clinics these are fortunately far less common nowadays. If progress is unsatisfactory the immediate post-operative complications to be looked for are haemorrhage, spreading peritonitis, ileus, pylephlebitis and suppuration in the wound. Later complications are residual abscess (especially pelvic or subphrenic), pleurisy or pneumonia and sequelae such as faecal fistula, sinus or hernia and intestinal obstruction from adhesions. Most of these give rise to typical signs and symptoms, although signs of some, for example subphrenic abscess, may be very insidious at first.

(a) Haemorrhage

Sudden pain

Sudden pain during the first few hours may be due to haemorrhage from a slipped ligature or leakage from the stump of the appendix. Haemorrhage is a rare complication today, but any complaint of the dressing "feeling damp" should at once suggest this possibility, and if the vessel is of any size (inferior epigastric) it must be ligated. If drainage has not been provided, bleeding from vessels in the appendix mesentery is more likely to lead to increasing pallor, weakness and abdominal discomfort than to any dramatic signs of internal haemorrhage. If progress is unsatisfactory and the signs point to haemorrhage it is far safer to open up the wound and deal with it; drainage should then be provided.

(b) Spreading peritonitis and ileus

General methods in the pre-operative treatment of these conditions have already been described. The post-operative problem is somewhat different in that the diagnosis of the original cause has by now been confirmed.

Paralysis of gut

If the ileus is supervening on a widespread peritonitis the general condition for several days may not appear to be affected and there may not be any rise of temperature or pulse rate at first; a gradually increasing abdominal distension appears with little if any pain or peristalsis and without localized tenderness; vomiting comes on slowly and is regurgitant in type. The pre-operative treatment should be continued with the addition of repeated doses of one-sixth of a grain of morphine. Aperients, enemas and peristaltic stimulants should not be used. Operation is not indicated, an enterostomy being usually ineffective in view of the widespread nature of the affection. It is in these cases that the Miller-Abbott tube may be of most use. (*See* Fig. 128.)

Regurgitant vomiting

Miller-Abbott tube

Kinking of gut

If on the other hand the ileus is due to the kinking of a coil of gut by adhesions from a localized abscess, the patient's general condition may show signs of deterioration on or about the first day; an increasing pulse rate is more significant than a rise of temperature; there is sometimes colicky pain, and abdominal tenderness and rigidity may persist; or there may be localized tenderness on rectal examination and possibly passage of mucus if the abscess is in the pelvis. Even in these cases much relief will be gained from the above measures, but when the condition is diagnosed, operation under spinal

Group (1), unperforated and ranging from acute catarrhal inflammation to actual gangrene, illustrates the low mortality of early operation. The deaths are usually due to intercurrent disease.

Group (2), in many of which the appendix was gangrenous and the peritonitis occupied a large part of the right side of the abdomen or pelvis, shows a comparatively low mortality.

Group (3), various types of abscess, also shows a reasonably low mortality. In twenty-one cases the appendix was not removed at the primary operation, and these included four which ended in death.

Group (4) shows the very high mortality in diffuse peritonitis. Some of these patients were very young or very old and others moribund on admission, factors which in varying proportions make or mar any short series of cases. Results in this group should be more affected than should be those in any other group by modern methods of treatment.

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[References to other titles are given under Appendicitis in t subject of Appendicitis is dealt with in the *British En Practice* (1936), Vol. 1, p. 729.]

APPENDICOSTOMY

See COLITIS

found to be dry, the pulse rate up and the temperature intermittent, there being no obvious cause elsewhere. Doubtful cases are more likely to be finally diagnosed by x-ray examination than by definite clinical signs. As soon as the diagnosis is decided and it is probable that the condition will not subside, all residual abscesses should be opened and drained by the most appropriate route.

(*f*) *Faecal fistula*

Tuberculosis

Barium enema

This is most common when the wall of the caecum has been involved, and as a rule it closes spontaneously. It may result from unrecognized tuberculosis. Failure to close may be due to some obstruction below, and this should be excluded by a barium sulphate enema before operative closure is attempted.

(*g*) *Persisting sinus*

Foreign body or actinomycosis

A persisting sinus, as elsewhere, is usually due to a foreign body such as a concretion or a mass of necrotic tissue, but actinomycosis should be thought of if there is much induration. Removal of the cause is the essential treatment.

(*h*) *Hernia*

Scar hernia is apt to result in any case in which prolonged suppuration has occurred, whichever incision is used. Inguinal hernia is alleged to follow the McBurney incision when the latter is made too low, the cause being injury to nerves.

12. RESULTS OF TREATMENT

Vital statistics show that the general mortality rate remains high and that the disease accounts for a large proportion of the deaths per annum in most civilized countries, especially the United States of America. On the other hand, the mortality in the published results of large hospitals and experienced surgeons is relatively very low and it is plain that there is room for considerable improvement in the unpublished results.

Dangers of purgation

The chief causes of the higher mortality appear to be the use of purgatives, delay in operating and, to a lesser degree, inadequate treatment or nursing. Delay is largely due to difficulties in diagnosis and unfortunately has been further encouraged by a misconception of the principles of the Ochsner treatment which, as already emphasized, is quite inapplicable outside a properly equipped surgical clinic. On the contrary, immediate operation has the tremendous advantages of being universally applicable save in very extraordinary circumstances, of clearing up any doubt in diagnosis and of resulting in a minimal mortality if practised with understanding in relation to the conditions found.

The writer's results in 1,026 consecutive cases are tabulated below.

(1) Limited to appendix			(2) Local peritonitis			(3) Abscess			(4) Diffuse peritonitis			Totals		
R	D	Per Cent	R	D	Per Cent	R	D	Per Cent	R	D	Per Cent	R	D	Per Cent
546	3	0·54	294	7	2·25	143	6	4·0	17	10	37·0	1,000	26	2·53

R = recovered. D = died.

myxoma, fibroma, lipoma, carcinoma and sarcoma. Their illustrations show three typical carcinoids, one adenocarcinoma and one sarcoma.

Previous pathological change

There is still difference of opinion whether some appendix tumours are hyperplastic or neoplastic. All tumour-containing appendices show some previous pathological change.

2. SIMPLE TUMOURS

(1) Fibroma

True fibroma of the appendix has seldom been recorded. Occasionally, the distal portion of the appendix appears as a bulbous mass of fibrous tissue superficially resembling fibroma. Massive fibromas have been described, but their origin is usually extra-appendicular. Kelly and Hurdon (1905) describe and illustrate a good example.

(2) Myxoma

An appendix containing a capsulated myxoma was removed by Mayo Robson in 1899 and demonstrated to the Leeds Medical and Surgical Society. Since then a number of myxomas have been described, their distribution being central, surface tumours (Kelly and Hurdon) or in the appendix mesentery (Laird and Nolan, 1942).

(3) Myoma

Leiomyoma occurs as a small unimportant capsulated tumour in the appendix wall. Like fibroids elsewhere it is liable to calcareous deposit.

(4) Lipoma

These growths are met with on the surface of the appendix near its base, and are probably examples of regional lipomatosis.

(5) Angioma

Angioma, of cavernous type, is a rarity. It may develop as a surface or intramuscular growth. Norment (1932) illustrates a good specimen.

(6) Adenoma

Although slight irregular polypoid proliferation of the appendix mucosa is not uncommon, true adenoma of the appendix is rare. Collins in 1932 collected sixteen cases from the literature, and two further cases have since been recorded. Sanes and Patchin (1942) record two polypi in an appendix lumen filled with blood, and suggest that such polypi might be one of the very rare causes of melaena. Most recorded cases had polypi elsewhere in the intestine, and this would suggest the possibility of malignant change.

Generally speaking, simple tumours of the appendix are associated with indefinite symptoms of appendicitis and do not constitute any additional problem for the surgeon at operation.

3. MALIGNANT TUMOURS

(1) Carcinoid

Description

The most important tumour in this group is carcinoid (*see* Fig. 129). There is still controversy over this descriptive term—introduced by Oberndörfer (1907). Kaufmann (1929) denounces it as "merely an expression of

APPENDIX–TUMOURS OF

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1. GENERAL

(1) Incidence

Assessment

36.] Tumours are seldom met with in the appendix. They constitute 0·3 to 0·4 per cent of all intestinal growths. The exact assessment of their incidence is complicated by the many tumour-like masses, encountered in the appendix region, which prove on examination to be inflammatory or granulomatous. Tumours also develop in the anatomical neighbourhood and involve the appendix extensively before symptoms develop. Seeded secondary growths are met with occasionally.

Many surgeons are still content with a brief "post-mortem" on the excised appendix before discarding it. In the most interesting tumour of the appendix—carcinoid—the majority of specimens will be missed by this casual method.

(2) History

During most of the last century pathologists regarded appendix tumours as merely metastatic, although Merling in 1838 and Rokitansky (1867) described primary growths in the appendix. In 1867 Langhans gave the first description of a carcinoid tumour of the intestine. Lubarsch (1888) mentioned this type of tumour as occurring in the appendix.

Classification

Stimulated by the increased incidence of appendicular disease during the early years of this century, a considerable literature has evolved on the subject of appendix tumours. Elting (1903) published the first series of malignant appendix growths. They numbered about forty and were nearly all found at necropsy. In their monumental monograph, Kelly and Hurdon (1905) offered a classification of appendix tumours. They listed polyp, myoma,

(iii) *Malignancy.*—As regards malignancy, Raiford (1933) gives the high figure of 5·9 per cent metastatic malignancy in appendix carcinoid as against 20 per cent in intestinal carcinoid. This estimate seems unduly high when only 16 cases—some doubtful—of metastatic spread have been reported out of hundreds of carcinoid appendices removed. Even when metastases have occurred, the outlook is not hopeless. Stewart and Taylor (1926) record the case of a woman, aged 31 years, who was alive and well 9 years after the removal of a carcinoid appendix with massive secondary deposits in the pelvis. The possibility of carcinoid suggests a paramedial exploration in all cases of chronic appendicitis—especially in females.

Prognosis

Paramedial exploration

(2) Carcinoma

The incidence of adenocarcinoma appears to be about 10 per cent of all appendix tumours. Kelly and Hurdon (1905) examined 11 appendix tumours histologically and found 9 carcinoids, one adenocarcinoma and one colloid carcinoma. Schuldt (1940) more recently published figures giving the same proportions.

Site

(i) *Adenocarcinoma.*—Adenocarcinoma usually develops near the base of the appendix, forms a considerable tumour mass, and has the same malignant potentialities as carcinoma elsewhere in the bowel. It is a tumour of middle life.

(ii) *Colloid carcinoma.*—Colloid carcinoma appears to be relatively more common in the appendix than elsewhere in the intestinal tract (26 per cent as against 7 per cent). The fallacy in these figures is that many mucoceles of the appendix are described as mucoid cancers. The first examples recorded (1867) were cautiously described by Rokitansky as "four cases of colloid tumours".

Clinical picture

The whole appendix is involved and greatly enlarged (*see* Fig. 130). The walls are thickened and the lumen moderately distended. The range of malignancy varies widely. When the growth is circumscribed, local resection of the appendix with its caecal



FIG. 130.—Mucoid carcinoma of the appendix. The appendix measured 8 5 centimetres × 2·9 centimetres. The lumen is filled with a bulky gelatinous tumour mass with ill-defined margins. There is no penetration of the peritoneal coat. The patient, a male aged 45 years, had intermittent pain in the right iliac fossa of 3 months' duration. He was well 8 years after operation.

perplexity", but the majority of authorities agree that it expresses the doubtful malignancy of the tumour with satisfactory accuracy. Hopping, Dockerty and Masson (1942) suggest "grade I malignancy (Broders), grade I adenocarcinoma (carcinoid)" as a more scientific description. Some American authors prefer paraganglioma (Christopher, 1939). Bunting (1904) pointed out the obvious resemblance in microscopical structure between carcinoid and basal-celled carcinoma. Rogg (1913) called attention to the cellular similarity between carcinoid and melanoma; Ewing (1940) admits a partial parallel between skin melanoma and carcinoid. The tumour develops in appendices which show old-standing obliterative changes. The growth usually occurs near the tip. The most prolific writer on the subject is Masson (1923, 1928). He considers that all carcinoids arise from aberrant Kultschitzky cells which invade the sympathetic nerve elements in relation to the crypts of Lieberkühn—frequently inducing irregular proliferative changes in the nerve elements and their cell stations. Masson conceived the various Kultschitzky cells as constituting an endocrine organ and terms these tumours endocrine adenomas—simple and malignant. Forbus (1925) supports this view.

Resemblance to other growths

Origin

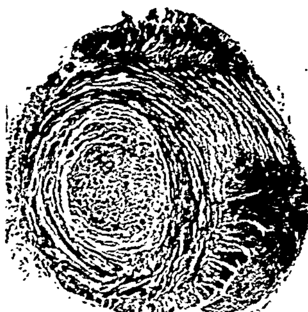




FIG. 129.—Carcinoid of the appendix (low power). The lumen and mucosa are replaced by a mass of anaplastic epithelial cells in clusters and strands; some invasion of the surrounding fibrous tissue is evident. The appendix did not show any naked-eye evidence of tumour. The patient, a female aged 26 years, had a history of 3 mild attacks of appendicitis.

In intestine

Although carcinoid is seen most frequently as an appendix tumour, an exactly similar growth is met with in stomach and intestine. It occurs as a nodular or stenosing tumour. The difference between the growths is biological rather than cytological. In the small and large intestine the incidence is multiple in 30 per cent of cases and metastatic spread is common. A single stenosing carcinoid is met with occasionally at the ileocaecal valve.

(i) *Incidence.*—Hopping estimates the incidence of carcinoid as 1 in every 200 appendices examined—a correct estimate, in my experience.

(ii) *Age and sex incidence.*—The incidence of appendix carcinoid is maximal from 15 to 25 years of age, and of intestinal carcinoid from 40 to 50 years of age. The sexes are equally involved.

(iii) *Malignancy*.—As regards malignancy, Raiford (1933) gives the high figure of 5·9 per cent metastatic malignancy in appendix carcinoid as against 20 per cent in intestinal carcinoid. This estimate seems unduly high when only 16 cases—some doubtful—of metastatic spread have been reported out of hundreds of carcinoid appendices removed. Even when metastases have occurred, the outlook is not hopeless. Stewart and Taylor (1926) record the case of a woman, aged 31 years, who was alive and well 9 years after the removal of a carcinoid appendix with massive secondary deposits in the pelvis. The possibility of carcinoid suggests a paramedial exploration in all cases of chronic appendicitis—especially in females.

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The whole appendix is involved and greatly enlarged (*see* Fig. 130). The walls are thickened and the lumen moderately distended. The range of malignancy varies widely. When the growth is circumscribed, local resection of the appendix with its caecal



Fig. 130.—Mucoid carcinoma of the appendix. The appendix measured 8·5 centimetres × 2·9 centimetres. The lumen is filled with a bulky gelatinous tumour mass with ill-defined margins. There is no penetration of the peritoneal coat. The patient, a male aged 45 years, had intermittent pain in the right iliac fossa of 3 months' duration. He was well 8 years after operation.



FIG. 131.—Sarcoma of the appendix. The appendix measured 10 centimetres × 1·7 centimetres. Its structure is entirely replaced by round-celled sarcoma, which has penetrated the peritoneal coat. The patient, a male aged 30 years, had constant pain in the right iliac fossa of 1 month's duration. He died 3 months after operation.

base gives satisfactory results. In many cases, however, the clinical picture is of general peritoneal dissemination. The larger the appendix the more likely is it to be a mucocele.

(3) Sarcoma

About two dozen sarcomas of the appendix have been described (*see* Fig. 131). Charache (1934) lists 22 cases, and adds a case of *leiomyosarcoma* which evidently originated in the caecum and involved the appendix in its spread. All the cases had symptoms of disturbance in the right iliac fossa of some duration. The sexes were equally involved and the ages ranged from 4 to 55 years. The prognosis is bad in all cases. In spite of the unfavourable outlook, however, resection of the ascending colon as for carcinoma should be attempted in all cases where sarcoma or adenocarcinoma of the appendix is definitely diagnosed. The only contra-indication is the presence of distant metastasis.

Prognosis

Treatment

4. TUMOUR-LIKE CONDITIONS

(1) Schwannoma

In addition to classical tumours and implanted tumours, some tumour-like conditions occur in the appendix.

Changes in sympathetic nerves

Masson (1923) first called attention to the changes which are seen in the surrounding sympathetic nerves in cases of carcinoid. More recently other authors have devoted attention to similar nerve changes in appendices when the lumen is partially or totally obliterated. Hosei (1933) described these changes as neurogenic appendicitis. Fein, Hanan and Seidler (1938) described the condition as plexiform neuroma and found it in 202 cases out of 600 successive appendicectomies. Laird and Nolan (1943) object to these growths being described as neuromas, because most of these tumours are derived from elements of the sheath of Schwann mixed with a scanty number of altered

Kultschitzky cells. He suggests the term, schwannoma, as being more truly descriptive of the tumour. These appearances are seen quite commonly in the nerve elements and ganglion cells of appendices showing obliterative changes, and it is difficult to accept them as true tumour formation. The obliterative process itself is poorly understood. It cannot be regarded as simply a senile change, as it occurs mostly in young individuals. It is associated clinically with symptoms of chronic appendicitis with pain as the prominent feature.

Clinical association

Although there are some points of resemblance between schwannoma and carcinoid, the two conditions must be regarded as separate entities.

(2) Endometriosis

This is rarely seen. It develops as a surface transplant from ovary or tube, and may penetrate all layers of the appendix (*see* Fig. 132). On the surface it may be mistaken for angioma.



Fig. 132.—Endometriosis of the appendix (low power). Transverse section of the appendix, showing extensive invasion of the meso-appendix and muscular coat, by islets of endometrial acini—some of which are cystic—surrounded by their cytogenic mantle. The patient, a female aged 35 years, complained of intermittent pain in the right iliac fossa of some months' duration.

Description

(3) Melanosis

Battle (1913) described four cases of "black" appendix. The condition involved the mucous surface, which appeared partially or completely black. The pigment is a melanin-like substance contained in masses of cells lying below the mucosa. These cell aggregations may be interpreted as tumour formation. The condition is met with more commonly in the colon as a result of stasis or obstruction, but may occur in the appendix without obvious cause (Stewart and Hickman, 1931). Simon places its frequency as 10 per cent of all appendices removed by operation. It is seen most often in females.

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ARACHNOIDITIS

See MENINGES

ARTERIES

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1. SURGICAL ANATOMY

The arteria wall

37.] An artery has three coats: (a) an outer, the *tunica adventitia*, of loose connective tissue, in which run the vasa vasorum which provide the blood supply of the arterial wall, and the vasomotor nerves which control its calibre, chiefly by mediating changes in normal constrictor tone; (b) a middle coat, the *tunica media*, of circular smooth muscle fibres and elastic tissue, the former predominating in medium-sized and smaller arteries, the latter in the large trunks; this coat is the one which " holds " sutures; (c) an inner coat, the *tunica intima*, of elastic tissue smoothly covered by a glistening layer of endothelial cells.

The sheath

In addition, large arteries are surrounded by a condensation of fibrous tissue called a sheath, which must be peeled off before any local operation on the vessel is undertaken.

Abnormalities

Abnormalities in the arrangement of the arteries are not uncommon, and unless they are borne in mind, may be perplexing during an operation.

The innominate artery may be absent, its branches arising directly from the aorta; or there may be both right and left innominate arteries. The right common carotid artery may arise to the left of the median line, and reach the right side by passing in front of the trachea or behind the oesophagus. The left common carotid, the right common carotid and the right subclavian arteries may arise from a common trunk. The subclavian artery may course through or in front of the scalenus anterior muscle; in its normal position behind that muscle it may be accompanied by the subclavian vein. Occasionally the axillary artery divides directly into the radial and ulnar arteries, or there may be a high division of the brachial artery. Not infrequently the ulnar artery lies subcutaneously upon the superficial flexor muscles.

The inferior gluteal artery may persist as the main artery of the lower limb, becoming continuous with the popliteal artery. In such a case the femoral artery is small, terminating in profunda and circumflex branches. When the femoral artery is normal in size, the level of origin of the profunda is subject to great variations, and it may arise from the posterior or the medial aspect of the femoral trunk. The lateral circumflex artery may arise from the femoral artery and not, as is normal, from the profunda. The bifurcation of the popliteal artery may be higher or lower than normally. The posterior tibial artery may be replaced by the peroneal artery, and the dorsalis pedis artery by the perforating branch of the peroneal artery.

Arteriography

The arrangement and patency of any arterial system, and the site of aneurysms and arteriovenous fistulae, may be determined by arteriography, which involves the introduction of a radio-opaque substance into the lumen of a main artery, and immediate radiography.

Technique of injection

General or local anaesthesia may be used; for the lower limbs spinal anaesthesia is ideal. The artery is exposed through an incision in its line; it is not freed from its sheath. A suitable opaque medium is Per-Abrodil Forte (Diodone) (50 per cent), warmed to body temperature and injected by a 10-cubic-centimetre Record syringe with an eccentric nozzle carrying a No. 19 needle. The medium is rapidly injected, and the exposure made as the injection is completed. For the femoral artery, 10 cubic centimetres of medium is sufficient; for the subclavian or axillary artery 5 to 8 cubic centimetres. Some

prefer to make the injection while the circulation is controlled by a sphygmomanometer cuff, placed above the site of injection. After withdrawal of the needle, any oozing from the puncture is readily controlled by the pressure of a warm moist swab.

Complications

Complications are rare. Thrombosis at the site of injection has been recorded, and also systemic reactions including erythematous eruptions, nausea, vomiting and respiratory distress, none of which is serious.

2. SURGICAL PHYSIOLOGY AND PATHOLOGY

Vasomotor control

The quantity of blood traversing an artery varies with its calibre. In a healthy vessel this is controlled (a) chiefly by changes in the tonus of its circular muscle fibres imposed by its vasoconstrictor nerves, which are detached at intervals from adjacent somatic nerves to join the periarterial nerve plexus; (b) by a few vasodilator fibres reaching it in the same way; (c) in the case of muscular branches, by the chemical influence of local metabolites, which have a dilator action. Arterial degenerations may lead either to narrowing or to widening of the lumen; an artery may be plugged either by an embolus or by a thrombus, and the current within it may be wholly or partly diverted as the result of a wound.

Tests of arterial sufficiency

It is often necessary (as after wounds or ligations, and in obstructive arterial disease) to make a clinical assessment of the adequacy or otherwise of arterial input. The pulses are unreliable because rigid arteries may be transmitting a fair stream of blood, and because the collateral circulation, adequate though it be, may not restore the distal pulses. In a warm environment and in the absence of shock, coolness of one limb indicates diminished circulation. If the limb is placed at the same level as the heart, and a distal superficial vein is emptied by stroking with a finger, rapid refilling of the emptied vein indicates that a sufficient amount of blood is reaching the periphery. Other points in clinical examination are referred to in the section on Embolism.

Collateral circulation

When the flow through a main artery is much reduced or stopped, blood may still reach its territory through alternative channels. The development of this *collateral* circulation is of great importance in arterial lesions, since its adequacy determines the life or death of parts distal to the point of reduction of flow. The ultimate total collateral circulation is the sum of the flow through three components: (a) pre-existing anastomotic vessels, such as are normally present round joints, which are available at once, and which soon dilate in response to the additional demand upon them; (b) finer capillary anastomoses, often situated in muscles, which become effective somewhat later, and which increase their contribution with time as a result of dilatation; (c) finer anastomotic arteries which, over a period of days, months or even years, grow in calibre, in thickness of wall and in length, so that they become tortuous. Thus the development of maximal collateral circulation takes some time.

Clinical application

From this important aspect of the pathological physiology of arteries follows the clinical rule, that in treating arterial lesions the surgeon should delay as long as possible before embarking on any operative procedure during which the necessity of ligaturing a main artery may arise. In young and healthy subjects an interval of two to three months is generally regarded as suitable, but this may need to be extended when, as in arteriosclerosis, the total

capacity of the arterial tree is reduced and the collateral vessels cannot readily dilate.

3. INFECTIONS AND DEGENERATIONS

(1) *Acute arteritis*

Acute arteritis is uncommon, the wall of an artery being relatively resistant to infection. It may occur as a consequence of the lodgement of an infected embolus in bacterial endocarditis. The results vary from stretching of the infected wall to form an aneurysm, to rapid destruction of all its coats with secondary haemorrhage. The walls of an artery which traverse a septic cavity or area may also become infected, particularly in wounds in which a missile has bruised the vessel, or when it has been subjected to the local pressure of a fragment of bone or of a rigid drainage tube. Local thrombosis may occur, the arterial wall may be weakened so that an aneurysm forms, or secondary haemorrhage may occur. Efficient early treatment of wounds and modern chemotherapy have greatly reduced the incidence of this form of acute arteritis.

In bacterial endocarditis

In septic cases

(2) Atheroma

Atheroma is a patchy lesion of the tunica intima, which may end in the disappearance of the endothelial cells over the affected patch, leaving an area of fatty or calcareous degeneration. It affects both large and small arteries, and is of importance surgically because it weakens the vessel wall, and may provide starting-points for the formation of thrombi from which emboli may become detached.

(3) Arteriosclerosis

Arteriosclerosis is a generalized change, often though not always associated with a raised blood-pressure, and characterized by a deposit of fibrous tissue in both tunica intima and tunica media. Small arteries (for example cerebral arteries) may give way, but generally the major clinical problem is the ultimate left ventricular failure.

(4) Syphilis

Syphilitic disease chiefly affects the middle coat of the aorta and of smaller arteries, and is characterized by cellular replacement of the normal tissue of the tunica media. In syphilitic endarteritis, intimal thickening may proceed to obliteration of the lumen of small arteries. The end-results of syphilitic arterial disease include the production of weak areas in the walls of larger vessels, which may stretch, and nutritional lesions resulting from ischaemia.

Endarteritis obliterans

(5) Thrombo-angiitis obliterans

Thrombo-angiitis obliterans may affect any artery in the body, but is most often encountered in the legs and arms. It is a disease of males in middle life, the incidence of which appears to be increasing. Segments of the arterial tree (and its companion veins) are gradually blocked by the deposition of thrombus, either in a progressive manner or in a series of waves of thrombosis. For a time the collateral circulation may be adequate, but ultimately nutritional lesions and gangrene occur—sequels usually accompanied by severe pain.

The surgical importance of these pathological changes depends upon two features: (a) they are irreversible and (b) they are often progressive. The

Surgical importance

possible clinical implications of their presence may be conveniently summarized under three headings.

(i) *Local effects.*—Weakening of the arterial wall, resulting in aneurysmal dilatation or haemorrhage (acute arteritis, atheroma, syphilis); and thrombosis (acute arteritis, atheroma, thrombo-angiitis obliterans).

(ii) *Distant effects.*—Ischaemia, leading to limited nutritional lesions or to gangrene. Operations on ischaemic tissues are followed by uncertain healing, there is increased liability to sepsis, and the trauma of operation may of itself be enough to cause an accentuation of the ischaemia, and so to lead to more widespread or more profound nutritional lesions (all types enumerated above). When muscular branches are affected, and a muscle is required to perform work for which its blood supply sooner or later becomes inadequate, cramp-like pain in the muscle supervenes, termed intermittent claudication.

(iii) *General effects.*—Left ventricular hypertrophy, and subsequent decompensation (arteriosclerosis, syphilis), which influence adversely the prognosis of any major surgical procedure.

4. EXPOSURE OF MAIN ARTERIES

Positioning

Transfusion

Incision

Much of the difficulty of dealing with arterial lesions disappears when operative procedures are so planned as to provide wide exposures. Of great importance is the proper positioning of the patient on the operating table; the surgeon himself should supervise this, and see that the desired position will be maintained securely throughout the operation. When much loss of blood is a possibility, or much blood has been lost from vascular injury, a transfusion should be set up before the operation begins, the vein used being out of the way of the major field of operation. This must also be done if there is a likelihood that the administration of heparin will be required. In general, the incision is made in the line of the artery. In most cases muscles are separated from one another, so as to display the vascular cleft; but there is no objection to dividing a muscle near its origin or insertion, or where it is interrupted by a tendinous intersection—procedures which do not interfere with either vascular supply or innervation.

Many of the old anatomical exposures of arteries, which were of the nature of dissecting-room exercises, have been replaced by the methods introduced during World War I by Fiolle and Delmas, which provide wide exposure not only of the main arteries but also of the accompanying nerves ("neurovascular bundle") and of the origins of branches both of arteries and nerves. By the use of these methods the maximal number of collaterals can be retained, and ample room provided not only for dealing with vascular lesions, but also for repairing such complicating lesions as those of nerves. When an exposure has been completed it should be maintained by self-retaining retractors.

This section will deal with the larger arteries only; small vessels can be exposed directly, without the need for elaborate dissection.

(1) Carotid system (*See* Figs. 133 to 136)

Position

Incision

The patient is placed on his back, with a small pillow under the shoulders to hyperextend the neck, and the chin turned to the opposite side. The key incision for exposing the common carotid artery and its terminal branches is along the anterior border of the sternomastoid muscle. The lowest inch or

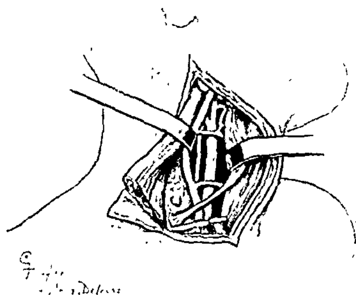


Fig. 133.—To show method of exposing the common carotid artery, and also incision to secure additional exposure of its proximal part.

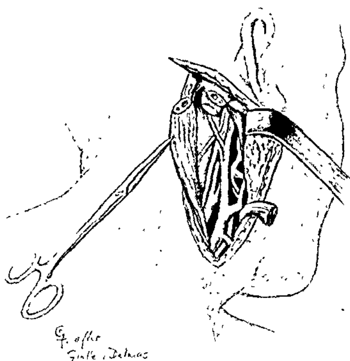


Fig. 134.—To show method of *exposing the* common carotid artery, and also incision to secure additional exposure of its distal part.

two of the right common carotid, the intrathoracic part of the left common carotid, and the terminal part of the internal carotid artery require additional exposure.

Proxima exposure

When more room is needed at the proximal end of the exposure, the incision is extended laterally from the lower end of the key incision, about one and a half inches above the clavicle, to reach the anterior border of the trapezius muscle. The sternomastoid muscle is divided on a director in the line of the skin incision, and the musculo-cutaneous flap so formed is retracted laterally. The structures in the floor of the wound are completely exposed by division of the tendinous part of the omohyoid muscle. At the end of the operation the muscles are repaired by interrupted non-absorbable sutures. (Fig. 133.)

Distal exposure

When the upper end of the internal carotid is to be exposed, the incision is carried posteriorly from the upper end of the key incision, above and parallel to the superior nuchal line, for three or four inches. The sternomastoid muscle may be divided close to its insertion, together with the mastoid process which is cut across by a guarded chisel (Fiolle and Delmas); or the pericranium may be incised above the insertion of the muscle, which is then freed by a sharp periosteal elevator, the mastoid process being removed by nibbling forceps, a modification which simplifies the final repair of the muscle. Whichever method is employed, the exposed mastoid air-cells should be plugged with bone wax. The intermediate tendon of the digastric muscle is then divided, the bellies of the muscle being retracted anteriorly and posteriorly. If the terminal part of the internal carotid (or internal jugular vein) must be divided close to the skull, it is better to secure the distal end by a continuous silk stitch rather than by a ligature; the latter is difficult to apply, and easily displaced. (Fig. 134.)

Before closing any of these incisions, the extension of the neck should be reduced by raising the headpiece of the table, and the chin turned towards the side of operation. The dressings are so applied that the sternomastoid muscle is kept relaxed for fourteen days.

(2) Innominate artery, intrathoracic part of left common carotid artery and first part of left subclavian artery

Although in certain cases (as when it is desired to apply a temporary ligature) the innominate artery may be exposed from the neck by following the right common carotid artery proximally, the advantages of wide exposure are so great that this vessel, and the other two segments mentioned above, are best displayed by the technique of Fiolle and Delmas. (*See* Figs. 135 and 136.)

Position

The patient lies on his back, in the position for the exposure of the carotid system.

Incision

The incision begins one and a half inches above the clavicle, at the anterior border of the trapezius muscle, passes to the median line above the suprasternal notch, and then curves downwards in the median line of the sternum to end beyond the level of the manubrium sterni. The clavicle is cleared at the lateral border of the sternomastoid muscle, and a malleable spatula passed round it to protect the subclavian vein and the pleura; the clavicle is then drilled in two places one inch apart, and divided by a Gigli saw midway between the drill holes. The sternomastoid muscle is divided on a director in the line of the incision. The posterior aspect of the sternum is now gently cleared

with a finger, and the manubrium sterni split in the median line to the level of the upper border of the second costal cartilage, either by a guarded chisel or by removing a piece of sternum at the lower end of the incision by a small trephine or Hudson's burr, and dividing the bone vertically by a Gigli saw passed by a suitable guide. The manubrium sterni is then divided by a cut from

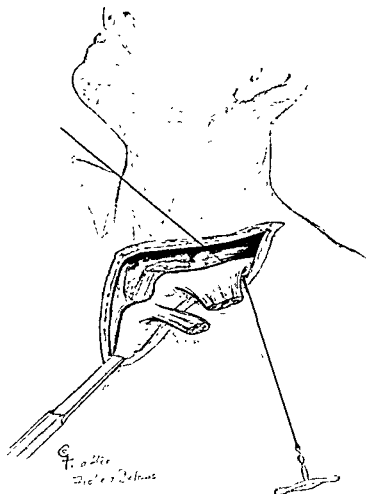


FIG. 135.—To show method of exposing the left common carotid artery and f part of the left subclavian artery; on the right side a similar dissection is emplo to expose the innominate artery. The sternomastoid muscle has been divided a the clavicle and sternum are shown in process of division.

the lower end of the preceding incision, and at right angles to it, which rea the appropriate edge of the bone at the upper border of the second costal c age. Finally, while the subjacent structures are guarded by a director, the first costal cartilage is carefully divided by a scalpel or, if calcified, by a pair of fine nibbling forceps. The trap-door to the thorax so fashioned is elevated laterally on its hinge of pectoralis major muscle. The pleura is gently brushed

aside by gauze upon the finger tips, and the vessels identified in the fatty tissue of the superior mediastinum; to complete the exposure, the innominate vein may be gently retracted downwards and laterally by encircling it with a moist tape. All manipulations in the vicinity of the vessels should be kept close to the arterial wall, which is the best safeguard against injuring other structures. At the conclusion of the vascular operation the trap-door is replaced; the clavicular fragments are apposed by a wire suture, and the

Closure

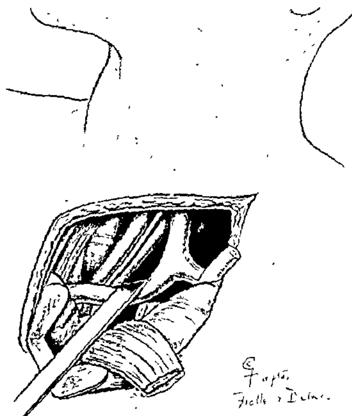


FIG. 136.—To show method of exposing the left common carotid artery, and first part of the left subclavian artery; on the right side a similar dissection is employed to expose the innominate artery. The innominate vein is being retracted downwards and laterally.

sternomastoid muscle is repaired. The manubrium sterni may also be wired, or secured by sutures passing through its periosteum, and finally the skin is sutured. Drainage is not usually necessary; if needed, the drain emerges at the lateral end of the supraclavicular wound. Copious dressings are applied and are retained by bandages which maintain the sternomastoid muscle in the relaxed position for fourteen days.

Alternative method

Although such an exposure is aesthetic, experience has shown that the bony part of the trap-door may be sacrificed without notable loss of function. Thus the bones may require piecemeal removal by nibbling forceps when a

lesion (such as a traumatic aneurysm) lies immediately behind the sternoclavicular joint, and is liable to be disturbed by the elevation of the flap. In such cases the removal of the inner end of the clavicle should be subperiosteal, the periosteum providing a strong layer for the reconstruction of the origin of the sternomastoid muscle.

(3) Subclavian and axillary arteries. (*See* Figs. 137 and 138)

The patient lies on his back with a small pillow between his shoulders. The scapula on the side to be operated on is drawn over the edge of the table, and

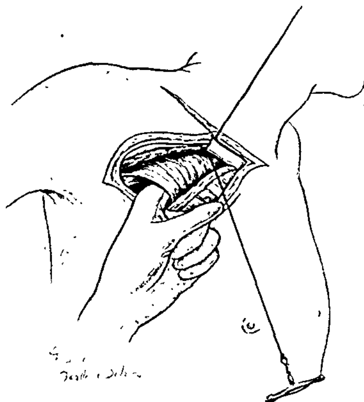


FIG. 137.—To show method of exposing the neurovascular bundle for the upper extremity; the pectoralis major muscle has been divided; the clavicle and the pectoralis minor muscle are prepared for division.

the arm is held at a right angle by an assistant. The chin is rotated to the opposite side. The incisions run (a) one inch above the clavicle, from the junction of the middle and outer thirds of the sternomastoid muscle to well beyond the anterior border of the trapezius muscle, and (b) from (a) at a point corresponding to the outer border of the sternomastoid muscle over the anterior axillary fold close to the lower border of the insertion of the pectoralis major muscle. The second of these limbs is completed first, by dividing the pectoralis major muscle in the line of the incision from clavicle to insertion, and by dividing the pectoralis minor muscle close to its insertion. As many branches of the acromio-thoracic artery as possible should be preserved. The clavicle

Incisions

aside by gauze upon the finger tips, and the vessels identified in the fatty tissue of the superior mediastinum; to complete the exposure, the innominate vein may be gently retracted downwards and laterally by encircling it with a moist tape. All manipulations in the vicinity of the vessels should be kept close to the arterial wall, which is the best safeguard against injuring other structures. At the conclusion of the vascular operation the trap-door is replaced; the clavicular fragments are apposed by a wire suture, and the

Closure

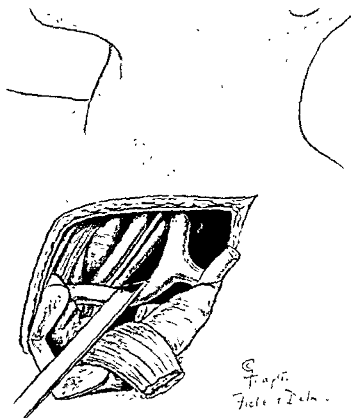


FIG. 136.—To show method of exposing the left common carotid artery, and first part of the left subclavian artery; on the right side a similar dissection is employed to expose the innominate artery. The innominate vein is being retracted downwards and laterally.

sternomastoid muscle is repaired. The manubrium sterni may also be wired, or secured by sutures passing through its periosteum, and finally the skin is sutured. Drainage is not usually necessary; if needed, the drain emerges at the lateral end of the supraclavicular wound. Copious dressings are applied and are retained by bandages which maintain the sternomastoid muscle in the relaxed position for fourteen days.

Alternative method

Although such an exposure is aesthetic, experience has shown that the bony part of the trap-door may be sacrificed without notable loss of function. Thus the bones may require piecemeal removal by nibbling forceps when a

muscles are sutured with non-absorbable sutures. If a drain is needed, it should emerge through a stab wound in the median axillary line. *Drainage*

Copious dressings are applied. The elbow is brought to the side and held upwards, and the forearm is placed on the chest with the fingers pointing to the opposite shoulder. If necessary, the sternomastoid muscle is also relaxed. The parts are maintained in this position by bandaging or by plaster of Paris for three weeks, after which movements are gradually permitted. *Position*

It is important to note that when a lesion of the second or third part of the subclavian artery has been present for some time, it may be found that the sheath of the artery as it passes over the first rib is much thickened and adherent

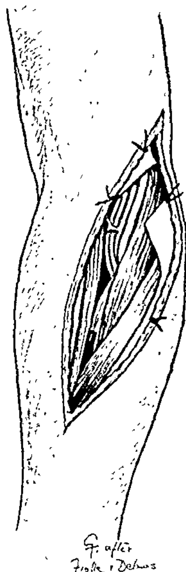


Fig. 139.—To show method of exposing the lower end of the brachial and the upper ends of the radial and ulnar arteries.

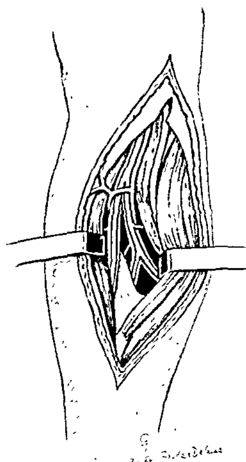


Fig. 140.—*To show method of exposing the lower* end of the brachial and the upper ends of the radial and ulnar arteries; strong retraction of the pronator teres muscle displays the course of the ulnar artery.

is bared close to the outer border of the sternomastoid muscle, a malleable spatula is passed deep to it, two holes one inch apart are drilled through it from below upwards, and the bone is divided between these. The subclavius muscle is severed. The assistant rotates the arm laterally, a manoeuvre which allows the operative field to open out, exposing the vessels and the nerves of the brachial plexus. In any further dissection the intimate attachment of the subclavian vein to the clavipectoral fascia must be remembered.

To expose the first and second parts of the subclavian artery in addition, incision (a) is prolonged medially to the medial margin of the sternomastoid

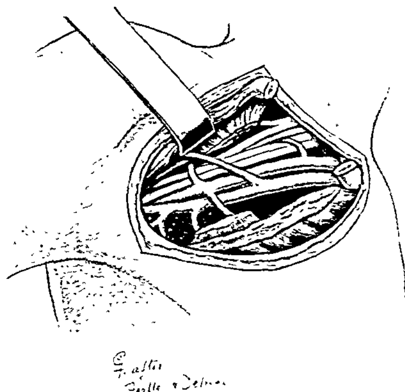


FIG. 138.—To show method of exposing the neurovascular bundle for the upper extremity; after division of the clavicle, and pectoralis major, pectoralis minor and subclavius muscles, the neurovascular bundle is well displayed.

muscle, which is divided on a director in the line of the incision. The medial fragment of the clavicle is rotated downwards and medially. The phrenic nerve is identified on the anterior surface of the scalenus anterior muscle, drawn medially by a moist tape, and the muscle is divided on a director close to its insertion into the first rib. Complete exposure is achieved by gently drawing the junction of the internal jugular and subclavian veins downwards and medially.

Closure

To restore the parts, the assistant raises the arm and rotates it medially. The clavicular fragments are approximated and immobilized by wiring, and the pectoralis minor, the pectoralis major and, if necessary, the sternomastoid

presence of a short pelvic mesocolon may necessitate mobilization of the colon by division of its lateral leaf of peritoneum, and retraction of the pelvic colon medially, care being taken to preserve the ureter. When the pelvic mesocolon is long, the artery can be approached directly.

(iii) *External iliac artery.*—The whole length of the external iliac artery can be conveniently exposed by the intraperitoneal route, which also facilitates

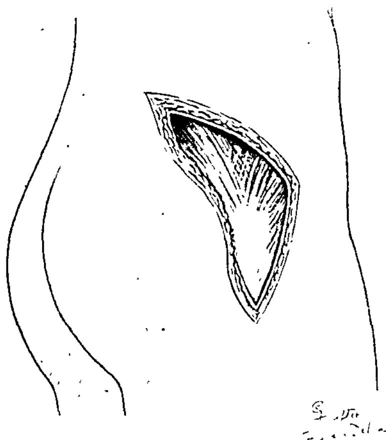


FIG. 141.—To show method of exposing the superior and inferior gluteal arteries; the incision has been made through skin and superficial fascia.

the preservation of the important collateral inferior epigastric and deep circumflex iliac branches. The testicular artery and the vas deferens, which cross the termination of the artery in the male, are easily avoided by keeping the dissection close to the arterial wall; the external iliac vein is displaced medially.

Alternative method

The external iliac artery may also be exposed extraperitoneally, by an incision half an inch above and parallel to the outer half of the inguinal ligament. The external oblique, the internal oblique and the transversus abdominis muscles are split in the line of the incision. The transversalis fascia is picked

to surrounding structures. Very careful dissection is indicated, in order to preserve collateral branches.

(4) Brachial, radial and ulnar arteries

High incision

The upper part of the brachial artery is exposed through an incision in the line of the vessel; its profunda branch is displayed by drawing the brachial artery medially and posteriorly by two or more tapes passed round the vessel, while the median nerve is similarly displaced laterally.

When the lesion involves the lower part of the brachial artery or the upper parts of the radial and ulnar arteries, the wide exposure of Fiolle and Delmas is much the best (*see* Figs. 139 and 140).

Position

The arm is abducted and rested on a table with the forearm in full supination.

Low incision

The incision first follows the medial border of the biceps tendon, and then slants laterally between the pronator teres and brachioradialis muscles. The *deep fascia and the bicipital aponeurosis are divided on a director in the line* of the incision. When the pronator teres and brachioradialis muscles are drawn apart from each other, the brachial artery, the radial artery and the beginning of the ulnar artery are readily exposed. A further segment of the *ulnar artery can be displayed by pronating the arm to allow of the fullest* retraction of the pronator teres muscle, and if necessary by dividing upon a director the upper fibres of the radial head of the flexor digitorum sublimis muscle under which the ulnar artery passes. By this manoeuvre the origin of the common interosseous artery can also be exposed.

Closure

The wound is closed by vertical mattress sutures which include both fascia and skin; but when the intervention has been for possible arterial spasm, it is best to limit the grasp of the sutures to the skin alone.

(5) Common, internal and external iliac arteries

Indications

These may need exposure to place temporary ligatures for the control of the *circulation in lesions about the root of the lower limb.* Moreover, the internal iliac artery is the *only* site where a proximal ligature is permissible to control secondary haemorrhage, in this instance from wounds of the buttock.

Position

Incision

The patient is placed in the Trendelenburg position. A paramedian *incision from umbilicus to pubis is made on the appropriate side,* the peritoneal cavity is opened and the small intestines displaced out of the pelvis.

(i) *Common iliac artery.*—The common iliac artery may be identified by tracing the bifurcation of the aorta. On the *right* side the *peritoneum over the artery is incised, care being taken* to preserve the ureter which crosses the termination of the vessel, and the artery is isolated by gently displacing laterally the right common iliac vein and the beginning of the inferior vena cava. On the *left* side the termination of the artery is crossed by the mesentery of the pelvic colon as well as by the left ureter. During the isolation of the artery care must be taken to preserve the superior rectal artery in the root of the mesentery. The left common iliac vein is displaced postero-medially.

Dissection

(ii) *Internal iliac artery.*—The internal iliac artery is traced from the bifurcation of the common iliac artery. The internal iliac vein is posterior to the artery and bound to it closely, the ureter is anterior, and the obturator nerve is lateral. On the *right* side the peritoneal incision is *made directly* over the artery; the vein is displaced postero-medially. On the *left* side the

The patient lies on the unaffected side, with the leg on this side flexed at hip *Position* and knee. The leg on the affected side is drawn backwards. This produces extension and lateral rotation of the hip-joint and relaxes the gluteus maximus muscle.

The incision begins at the middle of the greater trochanter, passes proximally *Incision*

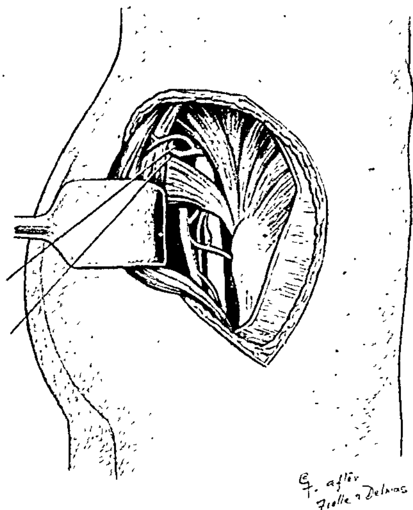


Fig. 143.—To show method of exposing the superior and inferior gluteal arteries; retraction of the gluteus maximus muscle displays the piriformis muscle.

for four inches and then runs parallel to the iliac crest and two inches below it, to the posterior superior iliac spine.

The thick aponeurosis over the trochanter (and possibly a bursa here) is incised so as to allow the insertion of a finger under the gluteus maximus muscle. The muscle is thus raised and the dissection deepened proximally in the line of the incision until the fascia covering its origin is reached. This is divided parallel to the iliac crest, the finger below the muscle accompanying the knife or the scissors throughout the whole length of the incision, to ensure

up and divided in the same line, and the peritoneum stripped upwards from the artery by gauze dissection. At the end of the operation the transversalis fascia and flat muscles are united by non-absorbable sutures. This exposure is notably less extensive than that provided by the intraperitoneal route, which should be preferred in lesions of the proximal segment of the artery and for dealing with aneurysms and arteriovenous aneurysms.

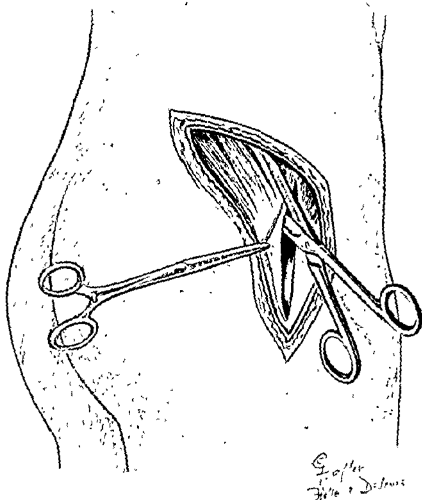


FIG. 142.—To show method of exposing the superior and inferior gluteal arteries; the gluteus maximus muscle is being divided.

Temporary ligation

When it is necessary to place a temporary ligature on any of the iliac arteries, the abdominal wound is temporarily closed with towel clips while the lesion in the thigh or the buttock is dealt with. The abdominal wound is then reopened, the ligature removed and the abdominal wall repaired.

(6) Superior and inferior gluteal arteries

When profuse haemorrhage or any arterial lesion occurs in the buttock, a wide exposure is necessary in order that the artery involved may be accurately identified and other structures respected (*see* Figs. 141 to 143).

trunk of this vessel, and its lateral circumflex branch disappearing under the rectus femoris muscle, are readily displayed by dissection and retraction. The medial circumflex branch may be investigated by putting lateral traction on the trunk of the profunda femoris artery by a tape, and retracting the lateral border of the pectineus muscle under which the medial circumflex artery courses.

Distal segment The lower part of the femoral artery and the upper part of the popliteal artery are exposed by an incision in the line of the vessel, continued to the

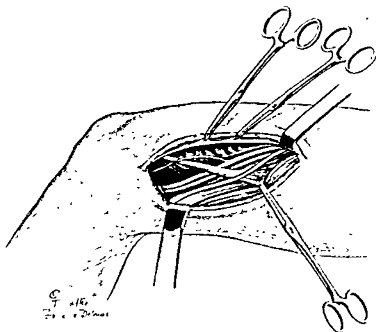


Fig. 145.—To show method of exposing the lower part of the femoral artery and the upper part of the popliteal; the aponeurotic roof of the subsartorial canal is retracted laterally; the sartorius muscle and tendon of the adductor magnus muscle are retracted medially.

adductor tubercle. (*See* Figs. 144 and 145.) The sartorius muscle is retracted medially. The tendon of the adductor magnus muscle is cleared by blunt dissection, and the aponeurotic roof of the subsartorial canal is divided. The latter is drawn laterally by forceps; the adductor tendon is similarly drawn medially, and may be divided to give access to lesions in the vicinity of the opening in the adductor magnus.

Closure Reconstruction is effected by closing the roof of the subsartorial canal, and the skin; it is unnecessary to stitch the adductor tendon.

(8) Region of bifurcation of popliteal artery. (*See* Figs. 146 and 147)

Position The patient lies on his face, with the knee-joint slightly flexed and the ankle plantar-flexed. *Incision* The incision begins in the middle of the popliteal fossa, and deviates to the medial side distally, between the two heads of the gastrocnemius muscle. The two heads of this muscle are separated, care being taken to preserve the considerable sural branch of the popliteal artery to each head.

that the correct plane is maintained. The main mass of the gluteus maximus muscle is now retracted posteriorly and held by a self-retaining retractor.

The piriformis muscle is displayed. Under its lower border emerge the inferior gluteal and internal pudendal arteries, the former being anterior. Above the piriformis muscle the superficial part of the superior gluteal artery appears; the deep part and the vessel itself may be exposed by retracting the postero-medial border of the gluteus medius muscle in an anterior direction.

Closure

To reconstruct the tissues, the edges of the musculo-aponeurotic layer of the incision are approximated by non-absorbable interrupted sutures, and



FIG. 144.—To show method of exposing the lower part of the femoral artery and the upper part of the popliteal artery; the sartorius muscle is retracted medially and the aponeurotic roof of the subsartorial canal is opened.

the skin closed. If a drain is needed, it should emerge above the greater trochanter.

For the first week the patient should be nursed prone or semi-prone.

(7) Femoral artery

Proximal segment

The femoral artery is exposed by an incision in the line of the vessel. The first part of the vessel is not covered by muscle, and includes the origin of the profunda femoris. At the apex of the femoral triangle the sartorius muscle passes over the front of the artery to its medial aspect. For proximal exposures the muscle is displaced to the lateral side, for distal exposures medially, to allow division of the aponeurotic roof of the subsartorial canal.

A difficulty—and it may be considerable—in proximal exposures may be the determination of the exact site of the lesion. If this is not apparent at once, it is best to display the origin of the profunda femoris artery by isolating a considerable length of the femoral artery and controlling it by three or four tapes, so that it can be gently swung from side to side. The long saphenous vein must be preserved. If the lesion affects the profunda system, the main

(9) Posterior tibial and peroneal arteries. (*See* Figs. 148 and 149)

The patient lies prone, with the knee-joint slightly flexed and the ankle-joint plantar-flexed. *Position*

Proximally the incision begins between the two heads of the gastrocnemius *Incision*

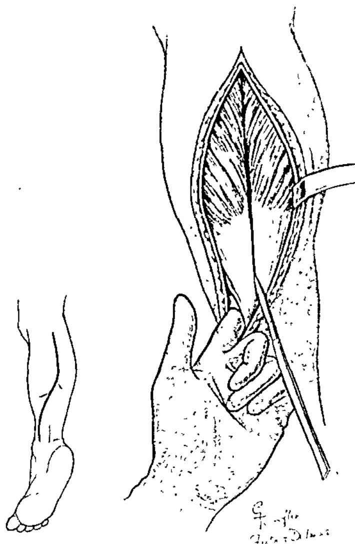


Fig. 148.—To show method of exposing the posterior tibial and peroneal arteries. The index finger identifies the plane of the vessels; the tendo calcaneus and gastrocnemius muscle are being divided in the median line.

muscle. Where the fleshy heads end it turns medially along the medial border of the tendo calcaneus, to end above the upper limit of a boot.

The dissection is begun distally by freeing the inner border of the tendo calcaneus, and inserting the left forefinger proximally under it to identify at once the plane of the vessels. The two heads of the gastrocnemius muscle are

The medial popliteal nerve is drawn laterally by a tape; its branch to the medial head of the gastrocnemius muscle may be separated proximally, and drawn to the medial side. The vessels are traced under the fibrous arch of the soleus muscle, which is then divided distally upon a director. Properly placed

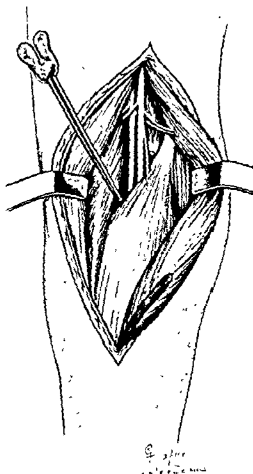


FIG. 146.—To show method of exposing the region of the bifurcation of the popliteal artery; the heads of the gastrocnemius muscle have been separated, and a director is introduced under the fibrous arch of the soleus muscle.

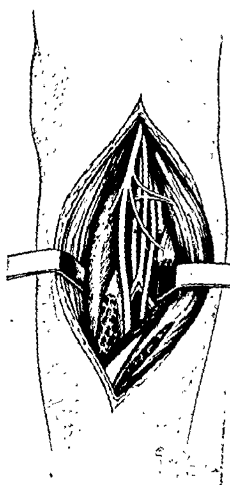


FIG. 147.—To show method of exposing the region of the bifurcation of the popliteal artery; the termination of the popliteal artery is exposed after division of the fibrous arch of the soleus muscle.

self-retaining retractors then display the distal part of the popliteal artery, its bifurcation and the origin of the peroneal artery from the posterior tibial artery. It may be added that, in a bloodless and adequately dissected field, a segment of the beginning of the anterior tibial artery may be displayed by this posterior route by dividing upon a director the interosseous membrane and the upper fibres of the tibialis posterior muscle.

Closure

It is best to limit the closure to cutaneous stitches; during convalescence the knee-joint should be maintained in extension and the ankle-joint at right angles.

first on one side, then on the other, while the edges of the incision in the sheath are held in fine forceps. When the vessel is free, a ligature of appropriate size is passed by an aneurysm needle. Silk ligatures are the most suitable. They should be sufficiently thick not to cut through the vessel wall. They should be tied tightly enough to bring intima to intima, but not so tightly that they disrupt the coats of the artery. This precise tension is best attained by applying the ligature to the artery while it is kept empty (*see* Fig. 150), a precaution which also prevents the first loop of the knot from being loosened by the force of systole. After the vessel has been divided, the distal ligature on the proximal end may be secured by a transfixion suture of arterial silk (*see* Fig. 151).

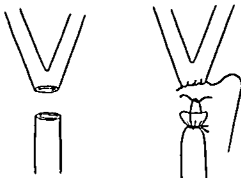


FIG. 152.—To show method of closing a main artery, *divided near the origin of a large* branch.

Small arteries

Smaller arteries may be ligatured without opening their sheaths, and without making any attempt to separate them from their venae comitantes if present.

Terminal suture

When a ligature is applied to an artery, permanent occlusion is brought about by the formation and organization of a thrombus for a short distance proximal to the ligature. If ligation is performed immediately distal to a large branch (as at the beginning of the femoral) or at a bifurcation (as of the common carotid), the opening of an essential collateral may be obstructed; moreover, there may be only a fringe of main vessel remaining distal to a large branch. In both these sets of circumstances it is better not to place a ligature on the main vessel, but to close its open end by a continuous suture (*see* Figs. 152 and 153).

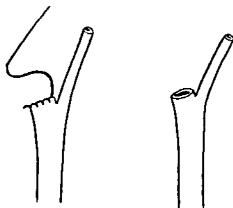


FIG. 153.—To show method of closing the *ends of a large artery, divided near its* bifurcation.

Simultaneous ligature of vein

It has long been the orthodox view that the risk of nutritional complications after ligature of a main artery can be reduced by simultaneous ligation of the main vein. This is never required when there has been time for adequate collateral circulation to develop; in acute lesions, the majority of surgeons advise simultaneous ligation of the vein.

Temporary ligature

Flow of blood through an artery may be temporarily controlled by a ligature of tape or of thick silk, applied so as to include a small moist swab or a short piece of rubber tubing of approximately the same calibre as the artery. This device may be employed to control circulation when the application of a

separated. An incision is then made through the expanded part of the tendo calcaneus, on the tip of the index finger. This finger is then reintroduced under the tendon at this more proximal level, and passed upwards to raise the soleus muscle. The finger is followed by a strong pair of scissors, angled on the flat, which divides the soleus muscle throughout the whole length of the incision, including the fibrous arch at its origin. Self-retaining retractors placed proximally and distally now display the vessels in the posterior compartment of the leg.

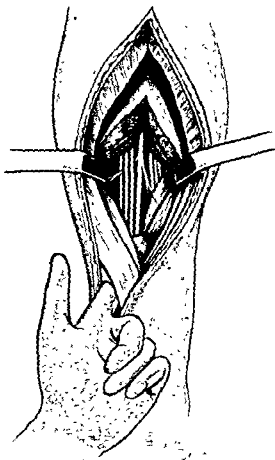


Fig. 149.—To show method of exposing the posterior tibial and peroneal arteries. The soleus muscle has also been partly divided to display the posterior tibial and peroneal arteries.

Closure

Closure is effected by interrupted non-absorbable sutures uniting the soleus and gastrocnemius muscles and the tendo calcaneus. If a drain is needed, it should emerge at the lower end of the incision. During convalescence the knee-joint is kept extended, and the ankle-joint at right angles.

5. LIGATURE OF ARTERIES

Object

The object of arterial ligation is permanently to stop the stream of blood at the point ligatured; this should be ensured by applying three ligatures and dividing the vessel between the middle and distal ligatures.

The artery to be ligated may be in a wound, or it may have to be exposed.

Large arteries

In the case of larger arteries (femoral, subclavian, carotid, innominate) the

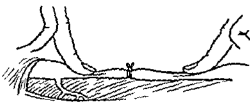


Fig. 150.—To show method of applying a ligature to an emptied artery.



Fig. 151.—To show method of anchoring a ligature applied to the proximal end of a divided artery.

artery should be tied inside its sheath. This is opened by a longitudinal incision and the artery is separated from the sheath by a broad aneurysm needle,

adjusts the wound edges in eversion. The surgeon then coapts the edges by a continuous suture, each stitch 2 millimetres from the preceding one, and completes the repair by tying the suture to the stay nearer him. Circulation is restored by releasing the tourniquet or temporary ligature; then the distal and finally the proximal local control of the segment. Any oozing at the suture line may be stopped by gentle pressure or by placing an extra interrupted stitch,

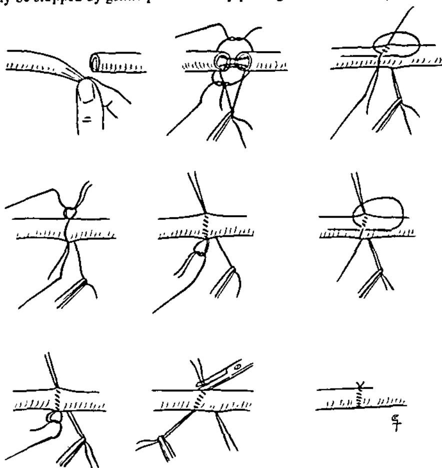


FIG. 155.—To show the stages in end-to-end anastomosis of an artery.

care being taken that the original stitch is not divided by the passage of the needle.

Long transverse wounds

When transverse wounds exceed one-third the circumference of the artery, the vessel should be completely divided and the proximal and distal segments united by end-to-end anastomosis (*see* Fig. 155). Before end-to-end anastomosis is begun, it must be clear that the ends will come together without tension, after any trimming that may be necessary. To secure this, it may be necessary to free the segments both proximally and distally, a procedure which may be impossible because important collateral branches leave either the proximal or the distal segment in the vicinity of the wound. The circulation is controlled by tourniquet or by temporary ligatures or rubber bands both proximally and distally. The ends of the arterial segments are cut square with a sharp knife or scissors. The adventitial coat is then removed from each

tourniquet is impracticable; at the end of the operative procedure the temporary ligature is divided upon the swab or tube.

Septic areas

If a ligature must be applied when sepsis is present, the wound must be so disposed that drainage is free.

6. TECHNIQUE OF ARTERIAL SUTURE

Requirements

The successful suture of arteries requires control of the circulation through the segments to be sutured, gentle and accurate dissection and, if possible, some method of preventing thrombosis at the suture lines.

Control of haemorrhage

Except in lesions in the proximal segments of the extremities, and in the trunk, control of the circulation is best attained by the application of a pneumatic tourniquet or, if the limb be too bulky for this, of a rubber bandage; either is applied while the limb is elevated. In lesions at the root of the upper extremity, a temporary ligature applied at the *beginning of the third part of* the subclavian artery diminishes bleeding; *in lesions of the groin* or buttock, a temporary ligature may be placed on the common iliac artery. The damaged segment of artery is isolated by passing rubber bands or tapes around the vessel proximal and distal to the lesion.

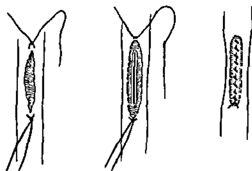


FIG. 154.—To show method of repairing a longitudinal wound in an artery.

Gentleness and accuracy are attained by the use of the finest procurable instruments, of sutures of fine silk on eyeless needles lubricated by sterile liquid paraffin, and by unhurried operating.

Heparin

Thrombosis may be prevented by the parenteral administration of heparin. This may be conveniently done by introducing into the reservoir of an intravenous drip-system heparin *in the proportion of 1,000 units to every 100* cubic centimetres of infusion fluid. In an average patient, a rate of about 25 *drops per minute raises the clotting time to about 15 minutes.* Administration of heparin should be begun 4 to 8 hours after the conclusion of the operation; the clotting time should be determined every hour for the first 4 hours thereafter, and the drip-rate increased or decreased according to the findings. Thereafter the clotting time (which should be maintained at between 12 and 15 minutes) should be determined twice daily for 3 days, after which heparin may be discontinued.

Sodium citrate

If heparin is not available, the edges of arterial wounds and the lumen of the segment or segments are wetted from time to time by sterile isotonic (3·8 per cent) sodium citrate solution dropped from a sterile pipette.

Longitudinal and short transverse wounds

Longitudinal wounds, and short transverse wounds, should be sutured in the long axis of the vessel (*see Fig. 154*). *As the first step,* the adventitia is gently stripped from the vicinity of the future suture line. If necessary, the edges of the wound are sparingly trimmed. A stay suture is placed beyond each end of the wound, the needle being retained on the stay farthest from the operator. Gentle upward traction on these stays by operator and assistant

femoral pulses. *If the embolus does not completely block both common iliac* arteries, the symptoms are of gradual onset, and one femoral pulse may continue to be palpable, though feeble, until th[illegible]on is completed by spreading thrombosis or by fragmentation of [illegible]olus.

Diagnosis

The diagnosis is only rarely in doubt, if a proper clinic[illegible]ination is made.

(4) Prognosis

When *the clot is allowed to remain, the prognosis* can be assessed in terms of nutritional disturbance of the limb. It is influenced (a) by the possibility of lodgement of additional emboli; (b) by the site of impaction of the embolus—in general the nearer this is to the heart the more severe the ultimate nutritional damage; (c) by the disposition of the embolus—thus it may occlude important collateral vessels as well as the main trunk, and so materially diminish the amount of blood traversing alternative routes; (d) by the condition of the collateral vessels—when these have lost their resilience or are diseased, collateral supply is inadequate.

Nutritional disturbance

Final nutritional state

If a sufficient collateral supply is available, circulation may return to the distal parts, often to the accompaniment of paraesthesiae. This is most likely to occur in the arms. At best, however, the distal pulses are diminished in volume and may remain absent; there is some atrophy of muscle and there may be anaesthesia of digits. At worst, nutritional changes follow, varying from loss of skin over the tips of digits to massive gangrene of all the tissues of the limb.

(5) Indications for surgical intervention

Permanence of block

There is no likelihood of recanalization of an embolus, and every likelihood that the block will extend both proximally and distally by thrombus formation upon the embolus. Therefore, unless there is some contra-indication, accessible emboli should be removed. The possible contra-indications to operation include advanced cardiac disease in which further emboli are likely, the presence of multiple emboli, one or more of which may be inaccessible, and such degenerative changes in the affected artery (for example arteriosclerosis) that suture of its wall would be precarious. To have any prospect of success, operation must be carried out early—best within 8 to 10 hours—in order to precede intimal changes at the site of the embolus and distal nutritional lesions.

Contra-indications

(6) Pre-operative management

The limb should be kept at rest, and exposed without covering to environmental temperature. Circulation through collateral channels is to be aided by warming the body to a temperature of about 43° C. Papaverine hydrochloride, ½ grain hypodermically every 2 hours, is said to produce dilatation of collaterals.

(7) Operative technique

Determination of level

It is first necessary to determine the site of the embolus from the history and local examination. *In spare subjects* and in superficial vessels this may be easy, pulsations of the vessel stopping abruptly at a definite point. When the pulse is poor and when the patient is obese, determination may be harder; particular attention should be paid to likely levels, for example the bifurcation of the common femoral.

by pulling it down with finger and thumb, cutting it flush with the open end of the segment, and allowing it to retract. The lumina are gently cleansed and moistened with heparin or sodium citrate solution, and the field of suture isolated by moist gauze swabs.

The edges are then "triangulated" by posterior, antero-medial and antero-lateral stay sutures, the needle being left on the posterior suture. Each side of the triangle is presented in turn to the operator, by traction and elevation of the stays; the first side to be sewn is from the posterior stay to the anterior stay farther from him. A continuous stitch is used, locked at intervals by tying it to each of the two anterior stays, and completed by knotting to its own short end posteriorly. Two diametrically opposite stays are enough for the common carotid artery.

The circulation is restored, and any oozing checked in the same way as after the repair of longitudinal wounds.

7. EMBOLISM

(1) Aetiology

Sources of emboli

Arterial emboli may be derived (a) from thrombi forming in the left auricle or left ventricle, in mitral stenosis, auricular fibrillation and coronary infarction; (b) from vegetations formed on the aortic or mitral valves, in bacterial endocarditis; (c) in degenerative arterial disease, from mural thrombi in the large arteries, or from a thrombus formed in an aneurysm.

(2) Morbid anatomy

Site of impaction

Emboli tend to lodge where arteries become narrower, that is, where large branches are given off, or a main trunk bifurcates.

Progress

At first the embolus tends to obstruct both main trunk and branch. It may be driven onward into either, or may itself provide a secondary embolus which plugs a previously patent branch. When an embolus becomes impacted, a thrombus forms both proximal and distal to it, and may fill the greater part of the arterial tree, for example of a limb, so occluding important collateral channels.

Infected embolus

The lodgement of an infected embolus may be followed by the rapid destruction of the arterial wall enclosing it, with resulting secondary haemorrhage.

(3) Clinical picture and diagnosis

The condition of the cardiovascular system may be known, or be ascertained on routine physical examination. Usually, but not invariably, the presenting symptom is continuous and severe pain in the distal parts of the affected limb. When the limb is inspected, at first the distal parts are pale, but soon the skin becomes cyanosed. The distal pulses are absent and, by careful palpation in the line of a main artery, it may be possible to determine the level at which pulsation disappears, and even to feel at this point a swelling, possibly tender, whose long axis is in that of the vessel. The distal parts slowly cool to environmental temperature. Power is lost first in the most distal muscles, and subjective numbness of the limb is associated with gradually ascending anaesthesia and, to a less extent, analgesia, the upper limit of which is often roughly circular.

Aortic embolism

Embolism at the aortic bifurcation produces in both legs sudden pain, loss of power, coldness to the level of the inguinal ligaments, and absence of

been restored in the femoral artery on this side, it is again controlled, and the bands round the other femoral artery are relaxed; if free pulsations are not immediately evident, similar manoeuvres are employed to dislodge the remainder of the embolus. When it is certain that the embolus has been completely removed, the incisions in the femoral arteries are closed.

(8) Post-operative care

If possible the patient should be heparinized (*see* p. 350). The dressing is kept in place without encircling bandages and the pre-operative routine restored. Warmth, power and freedom from pain return in that order. The parts should be kept at rest for 14 days.

(9) Results

With early operation, and healthy heart and arteries, the return of a normal circulation may be expected in more than half the cases. Late operation, unhealthy arteries, poor cardiac muscle and thrombosis at the suture line contribute to less satisfactory results; and in the least satisfactory gangrene may ensue.

8. SPASM

(1) Definition

Arterial spasm is a condition in which a long or short segment of an artery, or segments of a main artery and its branches, become contracted.

(2) Aetiology

Compensatory

Generalized arterial contraction is well known, both clinically and experimentally, as the final and despairing effort of the arteries to compensate for loss of blood volume in severe shock. Local spasm may appear after subcutaneous blows, after the impact of projectiles or near misses, after crushing injuries of leg or arm, after the impact of a fragment of a fractured bone, and after the prolonged application of a narrow tourniquet. Generalized spasm is the result of centrally imposed maximal constrictor tonus. Local spasm is a purely local affair, independent of extrinsic vasoconstrictor nerves.

Traumatic

(3) Pathology

Local spasm

Only local spasm falls to be considered in this section. The main vessels in the arm specially liable to spasm are the distal half of the brachial artery, the radial and the ulnar arteries; in the leg the distal half of the femoral artery, the popliteal and the posterior tibial arteries. Local spasm may affect total arterial input not only by narrowing the main vessel, but also by closing off the orifices of large collateral branches. Missiles and compression may directly affect collaterals as well as the main trunk. Any degree of spasm may be encountered, from slight reduction in calibre to one so marked that it is difficult to accept the affected trunk as a main artery. Spasm may be transient or persist for hours, and it may remain after gangrene of the part has occurred. Often it is associated with lesser degrees of arterial contusion.

Duration

(4) Clinical picture and diagnosis

Arterial spasm does not present a clinical picture of its own. Alone, or in association with actual arterial injury, it produces degrees of ischaemia which vary with the total distribution and the intensity of the spasm. In war wounds it may be difficult to determine the parts played by spasm on the one hand and

Anaesthetic

Although the operation may be carried out under local anaesthesia, when not contra-indicated by the general condition of the patient, general or spinal anaesthesia has the advantage of producing vasodilatation.

Control of circulation

The artery is exposed through an ample incision. The embolus may be identified as the cause of a bluish swelling of the artery, at which pulsation ceases; or, when it "tails off" distally, it will be recognized that, although the distal pulse may be detectable, it is diminished in volume. Circulation in the affected segment of artery must be controlled by gently passing round the artery above and below the embolus, or at a bifurcation above the embolus and round *both* distal branches, broad soft rubber bands of the type used to fasten documents, or tapes moistened in normal saline solution. By gentle traction on these, the currents of blood may be stopped. Over the distal part of the embolus the anterior wall of the artery is denuded of adventitia for a length of 2·5 centimetres (one inch) and a longitudinal incision about 1·5 centimetres (¾ inch) long is made into the artery while the circulation from its proximal end is controlled. This incision is kept open by stay sutures of arterial silk, inserted at the middle of each edge and caught in mosquito forceps. The embolus is lifted out, together with any distal "tail".

Incision

Removal of embolus

Blood flow from above is now tested by relaxing the proximal band; the remaining proximal part, if any, of the embolus may be ejected by this manoeuvre, and the full force of the stream and its pulsatile character may be immediately restored. Should this occur, the proximal band is tightened and the distal band (or bands) relaxed in turn, to demonstrate by the appearance of a free flow of blood that the lumen of the distal segment (or segments) is unobstructed. If the embolus remains unmoved, or is only partly ejected, and the arterial wall is healthy, an attempt may be made to dislodge it by gently milking the artery proximo-distally between finger and thumb. Should this fail, and when the arterial wall is diseased, a fine rubber catheter, with its tip cut off to present a terminal opening, is lubricated with sterile liquid paraffin and gently passed proximally until it is arrested. While suction is applied to the catheter by a Record syringe or suction pump, it is slowly withdrawn, bringing with it the whole or part of the embolus. This manoeuvre may have to be repeated. When all the clot has been removed, the bands are tightened again and the isolated segment is filled with heparin solution if available, or with sterile 3·8 per cent sodium citrate solution. The arterial wound is then repaired (*see* p. 350). Circulation is restored by relaxing first the distal band (or bands) and finally the proximal band. The skin incision is then sutured.

Aortic embolism

An embolus at the aortic bifurcation should not be approached directly. Both femoral arteries are exposed below the inguinal ligaments and a segment of each isolated as described above. While both segments are controlled, an opening is made in one. If the femoral pulses have not disappeared simultaneously, that in which the pulse first disappeared should be chosen because it has been obliterated by the larger portion of the embolus. The embolus may be freed by the suction method. In spare patients under general or spinal anaesthesia it may be guided down the common and external iliac by stroking movements in the line of these vessels, through the abdominal wall; in obstinate cases it may be necessary to expose the common and external iliac arteries through a muscle-splitting incision (*see* p. 340) so that the coaxing may be done directly on the vessels. When a free pulsatile flow has

Methods

(ii) obliteration of the lumen by a thrombus, from which there may be detached

(iii) an embolus which blocks the main vessel more distally, or one of its branches;

(iv) *stretching of the wall to form a delayed traumatic aneurysm*; and

(v) if infection is present, secondary haemorrhage from the giving way of the bruised area.

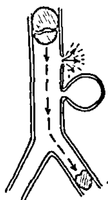


Fig. 156.—To show the possible sequelae of contusion of an artery.

(2) Clinical picture and diagnosis

The clinical features are those of interruption of a main artery (*see* p. 352).

The diagnosis can be made only after inspection and palpation of the vessel.

(3) Treatment

When contusion is suspected, the artery is exposed, if it is not already accessible through a wound. If the artery is of normal size or a little larger, bruised and converted to a solid rod, it is best to ligate it where it is healthy proximal and distal to the damaged segment and to remove this, in order to prevent the spread of thrombosis or embolism, or both. If the circulation to distal parts is imperilled, it is justifiable to attempt to improve it by temporarily restoring vascular continuity by some form of cannula or graft (*see* p. 361).

10. SUBCUTANEOUS RUPTURE

(1) *Aetiology*

An artery may be wholly or partly ruptured by some force applied from without, the classical example being rupture of the axillary artery during violent attempts to reduce a dislocation of the shoulder joint.

(2) Morbid anatomy

Complete rupture

Complete rupture of an artery favours the mechanism for the natural arrest of haemorrhage, because the three coats are torn at different levels, and the retraction and contraction of the inner and middle coats promptly close the lumen. In partial rupture bleeding is apt to continue, and then blood spreads widely in the tissue planes or, if confined to the site of rupture, forms a haematoma which may ultimately be converted to a traumatic aneurysm (*see* p. 358).

Partial rupture

(3) Clinical picture

There is a history of a blow or other violence, and signs of partial or complete interruption of a main vessel. In complete rupture subcutaneous blood-staining of variable extent is soon apparent; in partial rupture the parts are grossly swollen, and pulsation may be detectable, though not usually at first.

(4) Treatment

In complete rupture operation on the artery is usually unnecessary; in incomplete rupture the artery is exposed and ligatured above and below the

arterial injury on the other; in closed injuries the problem is to differentiate spasm from contusion with subsequent thrombosis. This is impossible without exploration.

(5) Indications for surgical intervention

It follows that the indication for surgical intervention is interference with the blood supply of a limb when there is uncertainty as to the exact state of the artery; then exploration is an urgent matter.

(6) Surgical treatment

This will vary with the precipitating cause. Soft-tissue wounds should be excised, and the artery carefully inspected. Fractures should be rapidly and accurately reduced, and maintained in reduction without constricting the limb. The most dangerous are supracondylar fractures of the humerus, and fractures of the upper end of the tibia.

Closed injuries If exploration is considered in closed injuries, it should not be delayed. This is because paravertebral sympathetic block, methods of inducing reflex vasodilatation, and drugs are without influence on arterial spasm. The urgent question to be answered is whether the condition is in fact spasm.

If the artery is contused, the affected segment is probably better excised, since thrombosis is likely. If the artery is in spasm, it may be difficult to identify it on account of its thinness. On no account should it be freed extensively, because the dissection is likely to throw into spasm the segments in process of isolation. Periarterial stripping and subadventitial injection of alcohol are also useless, nor should the contracted segment ever be excised. Local warmth, in the form of hot moist saline pads, often diminishes the irritability of the artery, and advantage may be taken of the open exposure to secure anatomical reduction of fractures, or to remove loose fragments of bone which might continue to press upon the vessel. Wound closure should be limited to the skin, other tissue planes and particularly deep fascia being left unsutured. In certain situations, as in the popliteal area, when there has been much swelling, part of the wound may have to be left open and later covered by a skin graft.

(7) Post-operative care

Apart from the control of fractures, this does not differ from that of any other condition which threatens the nutrition of the limb.

(8) Results

Gangrene Of itself spasm rarely leads to massive gangrene, although it may turn the scale in open wounds which have involved arteries. It is, however, a common *Ischaemic paralysis* cause of ischaemic paralysis of muscle, the most distressing example of which is the paralysis of the forearm and hand known as Volkmann's paralysis.

9. CONTUSION

(1) Aetiology and morbid anatomy

Causes Blows from without, either by missiles or through unbroken skin, and blows from within, by the ends of broken bones, may damage the walls of an artery. The tunica intima is usually damaged most. As a result there may follow (*see* Fig. 156):

(i) local narrowing of the calibre of the artery—arterial spasm;

(*see* p. 352) to slight coldness, slight numbness and slight loss of power, with diminished distal pulses. These evidences of ischaemia are not reliable clinical signs, unless any lost blood has been replaced and shock energetically treated.

Arterial haematoma

An arterial haematoma produces a local swelling, which may not at first pulsate. The distal pulse is usually present but diminished, and the pulse rate is increased. Often appearing within a few hours, rarely delayed for some days, the most characteristic sign is a short systolic murmur, heard best over the wound in the vessel, but later conducted distally. Auscultation must always be carried out over an artery which may lie in the track of any punctured wound, however small.

Arteriovenous fistulae

When there is a communication between artery and vein, there is little swelling because blood readily passes into the vein. A thrill is often present over the communication, and the stethoscope reveals a murmur continuous through both systole and diastole, loudest at the site of the fistula and conducted both proximally and distally. This has been likened to the whir of machinery, and it is accentuated during systole. It may be transmitted to the cardiac area.

Fall in blood-pressure

The presence of either a traumatic aneurysm or an arteriovenous fistula leads to a lowering of both systolic and diastolic blood-pressure in the distal segment of an affected limb, which may amount to 20 millimetres Hg; in arteriovenous fistulae the fall in diastolic pressure is greater than that in systolic. When the communication is of any size, digital obliteration of the fistula is followed by a slowing of the pulse rate—the Branham phenomenon—and by a rise in diastolic pressure.

Branham phenomenon

The site of a traumatic aneurysm or arteriovenous fistula, and its relation to collateral vessels, may be established by arteriography (*see* p. 367).

(4) Differential diagnosis

Acute vascular lesions which diminish the blood flow through an extremity include spasm, contusion with thrombosis, and partial or complete division of its main artery. When there is a local murmur, it can be inferred that the lesion is partial; moreover, the distal pulses may be palpable. When both distal pulses and local murmur are absent, the artery is thrombosed or in spasm; only surgical exposure and direct inspection will determine its exact condition.

(5) Prognosis

Expectation of life

The prognosis as to life will depend upon the size of the artery and of the wound, its accessibility, the speed with which haemorrhage can be controlled in accessible arteries and the possibility of replacing lost blood. The prognosis as to nutrition in the territory of a wounded artery also depends upon these factors and, in addition, upon the care of the limb during the critical period before collateral circulation is established. Collaterals may have been destroyed, or thrown into spasm, by the same or other missiles or by other agents. Moreover, there are vulnerable levels where collateral circulation is at best scanty. These include the popliteal, the femoral and the axillary artery distal to its subscapular branch. The following table (from the Medical

Nutrition

Collateral circulation

tear. The risk of nutritional complications varies with the artery torn, the anatomical level of the tear and the age of the patient—in short, with the chances of development of an adequate collateral circulation, which must be encouraged in every way (*see* p. 359).

11. WOUNDS

(1) Aetiology

In war almost any form of missile may wound an artery; in civil practice broken glass and pointed implements, for example pitchforks, are the usual causes.

(2) Morbid anatomy

The wound may result in partial or complete division of the vessel, and the pathological picture depends upon the freedom with which external haemorrhage can occur.

Arterial haematoma

In punctured soft-tissue wounds the leaking blood is confined and, although this helps to arrest the bleeding, the pressure of the resulting *arterial haematoma* may interfere with the circulation in collateral vessels, as well as obstructing what flow persists in the main vessel; in incised and lacerated wounds control of haemorrhage is the presenting problem. When an arterial haematoma forms, the opening in the arterial wall may be plugged by clot continuous with that in the surrounding tissues. The clot contracts, and later the pounding of cardiac systole hollows it out into a globular cavity continuous with the lumen of the artery, and ultimately partly or wholly lined by endothelial cells. The periphery of the clot condenses and is strengthened by condensation of the connective tissues in its vicinity to form a fibrous wall.

False aneurysm

The end result is the formation of a *traumatic* or *false* aneurysm on the artery, which nevertheless still transmits some blood to the periphery. Therefore the formation of a false aneurysm is at first a beneficent process which gains time for the development of collateral circulation; but such aneurysms never consolidate spontaneously. Indeed they tend to increase in size, and may compress neighbouring structures (nerves, oesophagus, etc.).

Arteriovenous fistulae

When the accompanying vein is also wounded, the artery may be thrown into communication with it either directly (aneurysmal varix) or with the interpolation of a false sac (varicose aneurysm). When these fistulae are large, a considerable proportion of the cardiac output leaks into the venous side of the circulation. This may be compensated by increase in pulse rate, but in many cases cardiac dilatation and ultimately decompensation are the end-results. Whereas the fistulous opening in aneurysmal varix may contract and even close, varicose aneurysms do not tend to heal.

(3) Clinical picture and diagnosis

External haemorrhage

The clinical picture may be dominated by external haemorrhage.

Ischaemia

When bleeding is slight or has been brought under control, the condition of the parts nourished by the artery is of first importance. These will always show some degree of ischaemia, varying from complete cessation of circulation

(2) Restoration of continuity by artificial tubes—of silver, vitallium, glass or plastic material. A shouldered tube of somewhat smaller calibre than the artery is used as a bridge, secured in the open ends of the vessel by ligatures (*see* Fig. 157). Heparin must be given continuously. After 4 to 5 days heparin

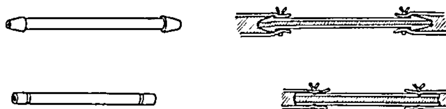


Fig. 157.—To show method of temporary restoration of continuity of an artery by the use of cannulae.

is stopped, the wound reopened 24 hours later, and the tube removed after ligature of the vessel proximal and distal to it.

(3) Restoration of continuity by a vitallium cannula lined by a free vein graft supplied by the accompanying vein, or by the long saphenous vein. The graft must be reversed in direction, lest valves interfere with the blood flow (*see* Fig. 158). Such a bridge may be left in position. Heparin is not absolutely necessary, since the tube is lined by an endothelial surface.

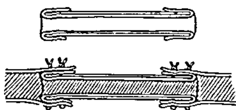


Fig. 158.—To show method of restoration of continuity of an artery by a vitallium cannula lined by a free vein graft.

(4) Restoration of continuity by free vein graft with two vitallium cuffs. Again the method is best explained by a diagram (*see* Fig. 159). Both this method and that described in (3) are still under clinical trial.

(5) Restoration of continuity by free vein graft and double end-to-end anastomosis.

(6) If restoration of continuity is impossible, ligature of both proximal and distal ends. When the division is close to the bifurcation of an artery (for example the common carotid), the distal end is best closed by a continuous suture, to preserve collateral circulation (*see* Fig. 153).

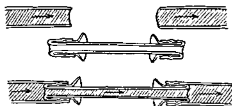


Fig. 159.—To show method of restoration of continuity of an artery by means of a free vein graft carried on two vitallium cuffs.

Longitudinal wounds

(ii) In longitudinal wounds, and transverse wounds of less than one-third of the circumference, the procedures adopted are:

(1) Longitudinal suture (*see* p. 350).

(2) The methods indicated under (i), (1) to (6) above.

(3) In open wounds, reconstruction of muscles and fasciae to limit bleeding and encourage the formation of a traumatic aneurysm; this method is limited in its application and the wound must be aseptic.

Contusions

(iii) In contusions, the damaged and possibly thrombosed segment must be

History of World War I) shows the risk attending interruption of the main arteries.

INCIDENCE OF GANGRENE IN SURGERY OF ARTERIES

Artery	Incidence of Gangrene	
	After wound	After ligation
Subclavian	8·8 per cent	0·0 per cent
Axillary	2·7 ,, ,,	1·4 ,, ,,
Brachial	4·0 ,, ,,	0·0 ,, ,,
Femoral	20·2 ,, ,,	17·2 ,, ,,
Popliteal	34·7 ,, ,,	26·6 ,, ,,

(6) Indications for surgical intervention

Immediate intervention may be required to control bleeding in incised or lacerated wounds. In punctured wounds which involve an artery, intervention is usually contra-indicated, since operative exposure reduces the possibility of formation of arterial haematoma and traumatic aneurysm, and the stimulus to the formation of collateral circulation which they provide.

Deferment

Operation

During the waiting period operation may become necessary: (a) on account of suppuration; (b) on account of rapid increase in the size of the aneurysm, which prejudices the remaining circulation in the main vessel and that in neighbouring collaterals, and which may compress nerves (intolerable pain) or conduits (difficulty in breathing and swallowing); (c) if external bleeding continues, because the necessary pressure dressing constricts both main vessel and collaterals. Otherwise a wait of 2 to 6 months is the best insurance against possible nutritional lesions after operation for the cure of the aneurysm.

Arteriovenous fistulae

In arteriovenous communications a similar period of delay is desirable; and indeed during this wait an aneurysmal varix may close. The only indication for early operation in such cases is evidence of early cardiac disability—tachycardia which persists in spite of rest, and cardiac dilatation detected clinically and radiologically.

(7) Pre-operative management

This includes safeguarding the ischaemic limb in the early stages and, if it is possible to wait, adequate rest both local and general.

(8) Operative treatment

(a) Primary control

The primary arrest of bleeding from an artery may be by (i) pressure dressings, (ii) forceps applied to both proximal and distal ends, and left in position, (iii) ligature of both proximal and distal ends, and (iv) the application of a tourniquet.

(b) In hospital

Divided vessel

(i) When the vessel is completely or more than one-third divided the following procedures are adopted:

(1) Restoration of continuity by end-to-end anastomosis (*see* p. 351). This may be possible if instruments and heparin are available.

as arteries. Persistence of part or parts of this embryonic network provides channels of communication between arteries and veins.

(3) Pathology

Site

Usually the vascular tree of the leg is affected, less often that of the arm, but any part of the body (such as an ear) may be the site of such communications. The fistulae may be single or multiple, and there may be associated widespread cutaneous haemangiomas, or haemangiomas of deeper structures (for example the femur).

Gigantism

As a result of the communication, overgrowth of the limb occurs, which affects all its components and gives rise to one form of "giant limb". If a lower extremity is affected, when the child begins to walk a lumbar scoliosis appears, concave to the affected side, with a compensatory curve in the thoracic region. When the opening is large, the veins of the part may show pulsation.



Fig. 162.—Congenital arterial anastomosis. Giant leg in child of 12 years, due to congenital arteriovenous fistula, showing cutaneous haemangiomas.

(4) Clinical picture

The mother is usually the first to notice the disproportion, and may also notice the increased warmth of the affected part. At a later age a spinal deformity may be obvious, and the child walks with a lurching limp. In a proportion of cases the presence of a cutaneous haemangioma may be noted (*see* Fig. 162).

(5) Diagnosis

Increased oxygen tension in veins

Blood from a superficial vein of the affected limb, which should be collected under liquid paraffin, shows an oxygen tension approximating to that of arterial blood. The skin temperature of the limb, as measured by a suitable thermo-electric couple, is 2° to 4° C. higher than that on the normal side. Arteriography is only rarely of assistance, the fistulae being usually multiple and affecting the smallest arterioles only.

Increased warmth

Gigantism, in association with raised cutaneous temperature, cutaneous haemangioma, and possibly pulsatile veins with an abnormally high oxygen tension, establishes the diagnosis. Dilated veins do not empty completely when the limb is elevated above the level of the heart.

resected between ligatures; or the gap may be bridged by one of the methods suggested in (i), (2) to (5) above.

Traumatic aneurysms

(iv) When a traumatic aneurysm is *present, it is freely exposed*, and the artery is isolated by careful dissection proximally and distally as close to the aneurysmal opening as possible, and temporarily ligatured above and below this. The sac is then opened, the clot removed and the walls inspected for the openings of any branches; at this stage the circulation should be restored, in order to identify small orifices. If any are present, they are closed by suture from within, after the circulation has again been controlled. When the sac is *dry, the feeding artery is divided* below the proximal ligature. Accessible parts of the sac may be trimmed off, but should not be unduly disturbed. Not infrequently one or more nerves are partly incorporated in the wall. If they are merely stretched over it, they should not be disturbed. Partial or complete division of such a nerve, or the presence of a hard neuroma, calls for resection and suture.

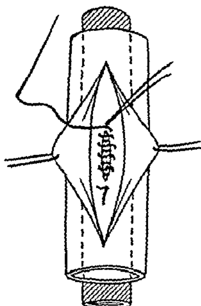


FIG. 160.—To show diagrammatically, method of repairing the arterial opening of an aneurysmal varix through a trans-venous exposure.

Arteriovenous fistulae

(v) (1) If the exact site of the opening of an aneurysmal varix can be identified, and it is of suitable shape, it may be repaired by opening the vein opposite to it, and suturing the arterial wound from within the vein, which is then ligatured above and below and divided (*see* Fig. 160).

(2) If the interposed sac of a varicose aneurysm is narrow, it may be ligatured close to the artery.

(3) In varicose aneurysm, and in aneurysmal varices unsuitable for repair, the most generally suitable operation is quadruple ligation. Both artery and vein are divided between ligatures applied above and below the communication and as close to it as possible (*see* Fig. 161).

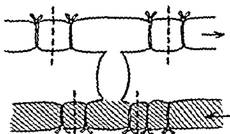


FIG. 161.—To show *diagrammatically* the operation of quadruple ligature in varicose aneurysm.

12. CONGENITAL ARTERIOVENOUS FISTULA

(1) Definition

Congenital arteriovenous fistula is a not uncommon condition in which one or more congenital openings exist between arteries and veins.

(2) Aetiology

The *original vascular network from which arteries* and veins are differentiated is an indifferent one, its vessels acting at one time as veins, at another

(5) Prognosis

The prognosis depends upon the accessibility of the aneurysm, the extent of its ramifications and its size. Untreated, the mass grows and may cause death from haemorrhage, either after an injury or following ulceration of the skin and infection.

(6) Indications for surgical intervention

All accessible cirsoid aneurysms should be operated on at the earliest opportunity.

(7) Operative technique

(a) Superficial aneurysms

Ligation and excision

In the limbs the circulation is controlled by tourniquet. The "tumour" is exposed by a generous incision, which should circumscribe the mass with a margin of at least an inch. All vessels approaching the mass are divided between ligatures, the mass is excised and the skin closed. In the scalp a flap is traced round the mass, leaving a pedicle proximally. The incision is deepened in short segments, the vessels exposed in each segment being secured and divided. The flap is then elevated, and during this procedure communications with the calvaria may be encountered; they are dealt with by ligature or diathermy on the "flap" aspect, and by bone wax or diathermy on the "skull" aspect. Finally the vessels entering the base of the flap are secured and divided; the flap is replaced and sutured, with provision for drainage at its most dependent point, and dressings are secured by a firm crêpe bandage. Blood for transfusion should always be available.

Technique in scalp

(b) Deep aneurysms

If the lesion is small and accessible, an attempt to dissect it out may be made. If excision is not complete, the "tumour" recurs. In recurrent cases and when the tumour is already large and widespread, if it is situated in a limb, amputation is the only satisfactory procedure.

Amputation

When the lesion is inaccessible, deep x-ray therapy may be tried, but the results are disappointing. (*See* Brain, Congenital defects.)

Radiotherapy

14. ANEURYSM

(1) Definition

An aneurysm is a localized dilatation of an artery.

(2) Aetiology

Mural weakness

Before an aneurysm develops, there must be a weakening of the wall of the affected artery. This may be the result of congenital deficiency (for example the small aneurysms on the circulus arteriosus), of trauma, of disease, including atheroma, diabetic arteritis and syphilis, or of infection. It is also held that the wear and tear of repeated angulation of an artery may weaken its wall, a factor which may help to explain the susceptibility of the popliteal artery. Moreover, high intravascular pressure must obviously contribute, and aneurysms complicating arterial disease are most common in the proximal segments of the aorta which take up the full force of cardiac systole.

Repeated trauma

Intra-arterial pressure

(3) Surgical anatomy

The dilatation may be uniform (fusiform type) or pouch-like (saccular type); or the cavity may be in the plane of the media, the blood either

(6) Prognosis

The only risk to life is accidental injury to a highly vascular "giant" part, such as an ear, with serious bleeding. The excessive growth of a limb continues until the epiphyses close. In the absence of orthopaedic treatment, the spinal deformity is permanent.

(7) Treatment

Treatment is as a rule non-operative, at least until growth ceases. To avoid the scoliosis, the lengths of the legs may be equalized by building up the sole and heel of the boot on the normal side. When the epiphyses have closed, an attempt may be made to equalize the lengths of the limbs by shortening the femur on the affected side and lengthening the normal femur.

Equalization of limbs

Surgery

Ligature of the main artery of a limb does not influence the condition; but when, as in the ear, the feeding arteries are accessible, they may be divided between ligatures through an incision encircling the organ, and the size of the ear reduced by a suitable plastic operation.

Attempts to obliterate dilated veins by the injection of sclerosing solutions are best avoided.

13. TUMOURS (CIRSOID ANEURYSM)

(1) Definition

The term cirsoid aneurysm is applied to a tangled mass of pulsating vessels.

(2) Aetiology

It is probable that the condition arises only when at its future site there has persisted some failure of obliteration of the primitive vascular network. The stimulus which starts this growing is usually local trauma.

(3) Pathology

Site

Most presenting cirsoid aneurysms are subcutaneous, but there may be widespread communications with muscular branches, and even bones may be affected. The classical example is the cirsoid aneurysm of the scalp, but any area or tissue may be the site of such a lesion. They are not uncommon in the brain. While the main feeding arteries are often enlarged anatomical branches, many small branch arteries enlarge, and much of the mass may consist of arterialized veins—a histological picture in keeping with the hypothesis of the origin of the mass suggested in (2). The rate of growth varies; it may be slow or so rapid as to suggest, when deep-seated, a sarcomatous tumour. Neighbouring structures may be displaced, and bones may be eroded.

Histology

Rate of growth

(4) Clinical picture and diagnosis

Superficial cirsoid aneurysms present as a subcutaneous mass of pulsating vessels. Deep-seated specimens form pulsatile tumours, which may ultimately betray their nature by the appearance over them of pulsating subcutaneous vessels. In the limbs the mere bulk of the mass may interfere with function. In late cases there may be ulceration of the stretched skin, and possibly severe haemorrhage. Each case presents a clinical picture peculiar to the situation of the "tumour" and to its rate of growth.

Pulsatile tumours

Arteriography

When the cirsoid aneurysm is deep-seated, an arteriogram may clinch the diagnosis, but rarely demonstrates all the many vascular connexions of the mass.

(6) Special aids to diagnosis

The site of a peripheral aneurysm may be determined by arteriography. Intrathoracic aneurysms may be identified by radiographic screening in various planes. Occasionally a radiograph will show calcification in the wall of an aneurysm.

The mobility of the vocal cords may be determined by laryngoscopic examination. An electrocardiogram may demonstrate a cardiac lesion. In syphilitic cases the Wassermann reaction may be positive, and in diabetes glycosuria may be present.

(7) Differential diagnosis

(i) *Peripheral aneurysm.*—There is rarely any difficulty in reaching the proper diagnosis. A tumour superficial to an artery may be raised at each systole but does not exhibit expansile pulsation; a tumour deep to an artery does not pulsate. Rapidly growing sarcomas may pulsate and may produce a systolic murmur, but they are seldom exactly in the line of an artery, and are fixed in all directions, and there may be clinical evidence of other deposits. *From tumour*

(ii) *Intrathoracic aneurysm.*—The difficulty here may be to distinguish between aneurysm and mediastinal tumour. Radiographic screening will usually, although not always, demonstrate pulsatile expansion in a mediastinal swelling which is an aneurysm. Occasionally a sarcoma which has eroded the thoracic cage may present difficulty, which may be resolved by the radiologist because in such cases the heart and aorta are normal. *From tumour*

(8) Prognosis

Occasionally an aneurysm may undergo spontaneous cure. Generally it increases steadily in size. It may rupture and cause death from haemorrhage, or the patient may die from cardiac complications when the aneurysm is near the heart.

In peripheral aneurysms there is the added risk that the collateral circulation may be inadequate, either because the collateral vessels are diseased or because they are compressed by the sac. In such cases more or less extensive gangrene supervenes. *Gangrene*

Emboli from a sac may precipitate gangrene of an extremity, or produce an infarct of a viscus. *Embolism*

(9) Indications for surgical intervention

The object of operation is either to remove the aneurysm or to produce conditions favourable to its thrombosis, by slowing the blood-current in it. Peripheral aneurysms should be operated on as soon as reasonable time has elapsed to permit the development of a collateral circulation, and before pressure features are significant. If the aneurysm ruptures or becomes infected, amputation is indicated if it is possible. Rarely it may be possible to promote thrombosis in saccular aneurysms of the aorta. Rupture of an aneurysm, or the occurrence of a complication such as infarction of the gut or of a kidney, may make operation imperative. Finally, the pain of inoperable aortic aneurysm may be relieved by sympathetic block. *Development of collateral circulation* *Complications* *Pain*

(10) Pre-operative management

This will vary with the site of the aneurysm. In peripheral and central aneurysms rest is essential, both general and, if necessary, local. Attempts to *Rest*

returning to the lumen of the vessel or bulging the adventitia (dissecting type). The sac may displace conduits (trachea, oesophagus) or compress nerves, veins, and the arteries providing collateral circulation.

Pressure effects

(4) Pathology

Wall of sac

The wall of an aneurysm is termed the sac. It is composed of fibrous tissue, derived partly from the adventitia and partly from condensation of the surrounding fibrous tissue. The part near the artery may be lined by endothelium. In aneurysms of some age and size, the interior is partly occupied by laminated clot, white and even partly organized towards the periphery, soft and red towards the centre. The constant pulsatile pressure of the sac erodes bone in contact with it (for example the vertebral bodies), but spares more resilient structures such as the intervertebral discs.

Clot

Thrombosis and cure

Spontaneous cure is possible as a result of thrombosis in the sac, the thrombus ultimately becoming organized into a mass of fibrous tissue; this process is confined to the saccular type. Usually the aneurysm steadily increases in size; it may rupture to the exterior, into a serous cavity such as the pleura, or into a conduit such as the oesophagus, an event which may be precipitated by infection of the sac. Portions of thrombus may escape from the sac to be swept into the arterial stream and to lodge as emboli.

Rupture

Cardiac disease

Aneurysms near the heart lead to hypertrophy of the left ventricle and ultimately to cardiac decompensation; and obviously there may be associated myocardial or valvular lesions.

(5) Clinical picture

Pulsation

Accessible aneurysms present in the line of a main vessel as swellings showing expansile pulsation. The pulsation can be stopped by proximal digital compression of the artery, and after release of the pressure the full extent of pulsation is not restored until the sac has been refilled by a few heart-beats. The pulse distal to an aneurysm may be diminished and delayed, and the blood-pressure is lower than that on the normal side estimated at a corresponding level. Over the aneurysm a systolic murmur may be heard. Signs and symptoms resulting from the pressure of the swelling may be present. Thus oedema and dilatation of superficial veins, pain and paralysis and, for example, difficulty in swallowing, may be features of individual cases.

Distal blood-pressure

Thoracic aneurysm

Aneurysms such as those of the thoracic aorta, or branches close to it which do not reach the surface, make known their presence either by cardiac signs such as dyspnoea, or by "neighbourhood" signs such as intercostal pain, cough from irritation of a recurrent laryngeal nerve, Horner's syndrome as a result of pressure on the cervical sympathetic trunk, dyspnoea and dysphagia. Aortic aneurysms may also give rise to bouts of pain referred to the sternal area, and to the inner side of the left and occasionally of both arms. Clinical examination may reveal signs of myocarditis, or a valvular lesion. Aneurysms of the abdominal aorta or its branches may interfere with intestinal motility, from their mere size, or even intestinal vitality as a result of thrombosis or embolism of a mesenteric artery; or they may lead to disturbances referable to various organs, such as haematuria in aneurysm of the renal artery, pain and splenic enlargement in aneurysm of the splenic artery.

Visceral aneurysm

One or more branches of the artery may have their origin in the sac.

(i) *Obliterative aneurysmorrhaphy.*—The circulation in the limb is controlled, the sac exposed, laid open by a longitudinal incision, and clots turned out. The orifices of entering and leaving vessels, and those of all branches, are then closed by continuous sutures of arterial silk. The walls of the sac are then folded into a number of layers, and anchored by tiers of silk sutures to each other and to the floor of the sac, the deepest tiers being inserted first. The skin wound is then closed. This technique has the advantage of limiting the operation to the interior of the sac, so that its surroundings are not disturbed and, in particular, collateral vessels are respected. However, there is left behind a mass of poorly nourished tissue, which is ultimately transformed into a dense scar which may compromise surrounding structures.

Advantages

Disadvantages

(ii) *Reparative aneurysmorrhaphy.*—This is possible only when the sac communicates by a relatively small aperture with the interior of an artery whose walls are healthy enough to hold sutures. The sac is laid open as in (i), the clot turned out, and the communication identified and dealt with as if it were a longitudinal wound. The sac is then cut away, or reduced in bulk, and its walls sutured to provide a buttress for the arterial repair.

Indications

Technique

(iii) *Reconstructive aneurysmorrhaphy.*—In this procedure an attempt is made to restore the lumen of the affected artery by a plastic method. The classical case is one in which the lumen is represented by a gutter in the floor of the sac. The sac is laid open, and the orifices of any branches except the entering and leaving vessels are sutured. In the gutter, and projecting into both entering and leaving vessels, is laid a length of rubber catheter, not too stiff and well lubricated with sterile liquid paraffin. A series of interrupted silk sutures is placed over this, in such a manner that when they are tied the lumen of the artery is restored. Stitches are inserted and tied at each end of the suture line in turn. When the middle of the line is approached, the final sutures are inserted but not tied. The catheter is then gently withdrawn and the remaining sutures are tied. The walls of the sac may be sutured together to provide support to the original suture line.

Technique

This method can be but rarely used. For its success, the arterial wall must be healthy enough to hold stitches.

Indications

(*g*) *Excision and grafting*

After the excision of an aneurysm, the continuity of the artery may be restored by grafting a segment of vein into the gap by double end-to-end anastomosis, or by the use of two vitallium cuffs (*see* p. 361). This procedure requires that heparin be available.

(*h*) *Production of thrombosis in sac*

In order to initiate or complete the obliteration of an aneurysmal sac by thrombosis, Colt has devised a trocar and cannula through which lengths of fine wire may be introduced into the sac. The method may be used for aneurysms of the thoracic and abdominal aorta, and on occasion has been highly successful. In thoracic aneurysms a small puncture is made in the skin over the most accessible part of the sac. In abdominal aneurysms laparotomy is performed and a small area on the posterior wall of the sac gently cleared. The cannula with trocar in position is firmly pressed into the sac, and the cannula steadied in position when, after withdrawal of the trocar, free arterial bleeding occurs from it. The wire, coiled in its container, is then pushed into the sac through the cannula by a special introducer, and opens out on reaching

Constitutional disease

increase collateral circulation round peripheral aneurysms, by compression of the main vessel immediately proximal to the aneurysm, do not seem to be more efficacious than the stimulus of the presence of the aneurysm which is already operative. Syphilis and diabetes are treated on the usual lines.

(11) Operative technique

(a) Ligation and excision

Close dissection of sac

This method deals permanently with the aneurysm with a minimum of scar tissue. It is suitable when collateral circulation has been well developed, as in young patients, and when access is easy, as in the carotid system. The aneurysm is widely exposed, and the entering and leaving vessel is ligatured and divided as close to the sac as possible; as a rule the accompanying vein must also be tied. The aneurysm is then peeled out of its bed by sharp dissection, during which the knife must be kept close to the sac; any branches from the sac are tied and divided as they are encountered. This dissection may be tedious, because surrounding structures, for example the medial popliteal nerve, may be very closely applied to the wall of the sac.

(b) Ligation and incision

In this procedure ligatures are applied to the entering and leaving vessels. The sac is then incised, the clot turned out and the cavity packed. The wound is left open and allowed to heal by granulation. This old method is now used only when an aneurysm has become infected.

(c) Proximal ligation

Close to sac

Distant from sac

A ligature may be applied to the main artery on the cardiac side of the aneurysm, with the object of slowing down the eddy of blood in the sac and so promoting thrombosis within it. This ligature may be placed close to the sac, as in innominate aneurysms, or it may be applied at some distance so that a large collateral vessel intervenes between the ligature and the aneurysm, a procedure which obviously materially reduces the pressure of the peripheral circulation. The classical example of distant proximal ligature is ligation of the femoral artery in the subsartorial canal in cases of popliteal aneurysm, the intervening artery being the descending genicular artery. After this procedure, feeble pulsation may return in the aneurysm after two or three days, but soon disappears as the clot consolidates. If pulsation returns after seven to ten days, it is produced by the collateral circulation, and it may be necessary to apply a second ligature nearer to the aneurysm.

When it is anatomically possible, the vessel should be divided between ligatures.

(d) Distal ligation

When the application of a proximal ligature is impossible, an effort may be made to produce stagnation in the sac by applying a ligature to the artery, or to one of its large branches, distal to the aneurysm. This procedure may be used in innominate aneurysms, the common carotid artery and subclavian arteries being divided between ligatures.

(e) Proximal and distal ligation

Both proximal and distal ligatures may be applied in innominate aneurysm.

(f) Aneurysmorrhaphy

Matas has devoted much attention to plastic operations on aneurysms. He divides them into three types.

(i) *Obliterative aneurysmorrhaphy.*—The circulation in the limb is controlled, the sac exposed, laid open by a longitudinal incision, and clots turned out. The orifices of entering and leaving vessels, and those of all branches, are then closed by continuous sutures of arterial silk. The walls of the sac are then folded into a number of layers, and anchored by tiers of silk sutures to each other and to the floor of the sac, the deepest tiers being inserted first. The skin wound is then closed. This technique has the advantage of limiting the operation to the interior of the sac, so that its surroundings are not disturbed and, in particular, collateral vessels are respected. However, there is left behind a mass of poorly nourished tissue, which is ultimately transformed into a dense scar which may compromise surrounding structures.

Advantages

Disadvantages

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Technique

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Technique

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Indications

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After the excision of an aneurysm, the continuity of the artery may be restored by grafting a segment of vein into the gap by double end-to-end anastomosis, or by the use of two vitallium cuffs (*see* p. 361). This procedure requires that heparin be available.

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the cavity of the sac. The cannula is then withdrawn, and any oozing from the puncture of the sac can be controlled by silk stitches tied over a small piece of muscle.

Choice of method

In some cases, for example aortic aneurysms, the only practicable method may be the production of thrombosis. In peripheral aneurysms a choice may be possible. On the whole, double ligation and excision of the sac is the most uniformly satisfactory technique, although the Hunterian ligature is simple and successful in many popliteal aneurysms. Aneurysmorrhaphy should not be attempted as an occasional operation, and the insertion of a vein graft also requires previous experience. It is to be remembered that aneurysms occur at one site of disease in a generally diseased arterial system, and that, in consequence, healing may be delayed and insecure and collateral circulation imperfect. Therefore the rule should be to select a technique which will fulfil its object with a minimum of local disturbance.

(*i*) *Sympathetic block*

Sympathetic block

White has shown that the pain of aneurysm of the aortic arch can be mitigated or abolished by paravertebral block. The technique is the same as for angina pectoris.

(12) Post-operative care

After operations for peripheral aneurysms the distal parts depend for nutrition upon collaterals. Dressings, bandages and splints must not constrict these. The limb is wrapped in a sterile towel and exposed to environmental temperature. A period of rest in bed for fourteen to twenty-one days is indicated.

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[References to other titles are given under Arteries in the Index Volume. The subject of Arterial Disease and Degeneration is dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 2, p. 39.]

ARTHRITIS–SURGICAL CONSIDERATIONS

By NORMAN CAPENER, F.R.C.S.
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1. CLASSIFICATION

38.] The subject comprises:

(i) Acute arthritis, including that occurring in the acute specific fevers.

(ii) Rheumatoid (atrophic) arthritis.

(iii) Arthritis of childhood (or Still's disease).

(iv) Menopausal arthritis.

(v) Osteoarthritis (hypertrophic, including traumatic arthritis).

(vi) Spondylitis, of three types: (a) ankylosing or atrophic, (b) osteoarthritic—also including traumatic—and (c) senile atrophic or osteoporotic.

(vii) Other arthritic conditions: (a) periarthritis, (b) vascular lesions, (c) synovial chondromatosis.

2. DEFINITION AND AETIOLOGY

The term "arthritis" is not confined to conditions conforming to the strict etymological implication of the term. This section is concerned with the more chronic forms, which, nevertheless, may arise acutely.

Not all are directly attributable to infection. Other factors—toxic, metabolic, and traumatic—are recognizable, and in the more generalized types more than one of these factors may be concerned, together with influences such as climatic, industrial and other environmental conditions, both physical and psychological. Constitutional features may be linked with those of heredity and premature aging.

(1) Rheumatoid arthritis

Role of infection

Rheumatoid arthritis is a general constitutional disease. Predominance of joint lesions may be explained on the theory of the "prepared soil", but though the role of infection is difficult to assess, such conditions as nasal sinusitis, dental infection, cholecystitis, appendicitis, colonic and genito-urinary infection, gingivitis and paronychia are not uncommon antecedents. While the treatment of them is clearly indicated, the surgeon should temper his optimism by recognizing that these may well be the effects of more ready susceptibility in a constitutionally enfeebled person.

(2) Osteoarthritis

Trauma

In this form of arthritis, although in some cases it is polyarticular, the element of trauma predominates. "Trauma" is interpreted very widely and comprises the reactions to mechanical stress in joints defective for reasons such as the following.

(i) *Congenital anomalies.*—Talipes, dislocation of the hip, etc.

(ii) *Developmental and infantile infective lesions, including the deformities of rickets.*—The various osteochondritides such as pseudocoxalgia (Perthes's disease); adolescent disturbances of bone growth such as coxa vara.

(iii) *Intra-articular fractures and dislocations.*—Fractures of the carpal scaphoid; compression fractures of the vertebral bodies, intercondylar fractures of the tibia or Pott's fracture-dislocation of the ankle, war wounds of joints; repeated injuries to intra-articular structures, for example knee meniscus lesions and so forth.

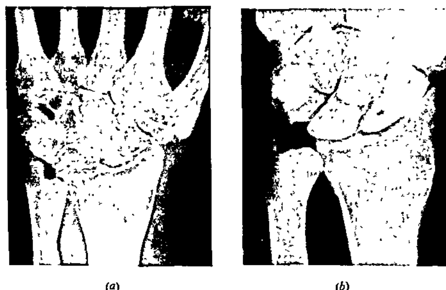
(iv) *The late results of injuries in the neighbourhood of joints* including degeneration of articular ends of bones the result of aseptic avascular necrosis (for example of the head of the femur after fracture) and abnormal stress occasioned by malunion of fractures, particularly in weight-bearing bones.

(v) *The late result of any disease of a joint.*—In particular in a joint damaged by a previous infective arthritis or neighbouring osteitis, including haematogenous osteomyelitis and osteitis deformans.

(vi) *Premature "wear and tear".*—In the more general forms of osteoarthritis the disease is frequently the manifestation of senility or of premature aging.

3. MORBID ANATOMY

Under the heading of "arthritis deformans" we are really dealing with two distinct diseases, although in some cases features of each intermingle. The two forms may be distinguished as atrophic (the rheumatoid) and hypertrophic (the osteoarthritic), and this terminology is convenient in indicating



(*a*) (*b*)

FIG. 163.—Arthritis of hands. (*a*) Relatively early rheumatoid case showing carpus. (*b*) Osteoarthritis secondary to ununited fracture of scaphoid for comparison of bone densities.

the chief differences in the morbid anatomy, particularly as seen radiographically (*see* Figs. 162 to 167).

Atrophic arthritis.—Here is to be found more clearly the reaction of an inflammatory process, particularly during the active phases of the disease. Vascular hyperplasia occurs throughout the constituents of the joint. The synovial membrane becomes swollen and develops granulation tissue and villous proliferation, with an effusion consisting partly of normal synovial fluid but also containing the products of the inflammatory process. The granulation tissue tends to spread over the articular cartilage, causing marginal absorption. The increased vascularity of the bone ends causes generalized osteoporosis, seen in skiagrams as thinning of the cancellous bone

Vascular hyperplasia

General atrophy

trabeculae and of the cortical compact layers with consequent lessened density throughout these parts. The articular surfaces of the bone as well as the subjacent cartilage take part in these hyperaemic changes; patchy absorption of the cartilage follows with adhesion of opposing surfaces. The granulation tissue which effects this adhesion eventually organizes into fibrous tissue and may lead to bony ankylosis.

Ankylosis

In the capsule and ligaments similar hyperaemic changes result in *fibrosis* and loss of resilience and, later, in contracture. In the muscles atrophy occurs



(*a*) (*b*)

FIG. 164.—Rheumatoid arthritis of hip-joint: (*a*) early stage; (*b*) one year later showing ankylosis.

early; this may be an active reflex process of an inhibitory nature in response to painful stimuli arising in the proprioceptive nerve endings.

Hypertrophic arthritis.—The changes here are those of degeneration, due to "*wear and tear*". *The synovial membrane does not take part so extensively* in the pathological process as it does in the atrophic disease. The beginnings of the degenerative change are to be found in many apparently normal knees early in middle life. It is an almost normal process, which may be aggravated by the causes already mentioned, and is found particularly on those articular surfaces most exposed to friction and pressure. Opposing surfaces are almost equally affected by fibrillation with fine wavy grooving of the articular cartilage in the lines of friction. The parts affected are those with the poorest blood supply. Regeneration of cartilage is unable to keep pace with the process of erosion, and thus gradually the subjacent bony cortex is exposed. The normal response of bone to mechanical stress is the deposition of new bone within *cancellous trabeculae and in cortical coverings*; thus subarticular "sclerosis" beneath cartilage erosion appears, a process which in the later stages becomes "eburnation". These changes are responsible for the clinical sign of grating.

Mechanical "wear"

Erosion

At the periphery *of the articular surfaces the reaction* is rather different. Here the covering cartilage is better nourished and so proliferation occurs,

Reaction



(a)



(b)



(c)

FIG. 165.—Arthritis of knee-joint (a) and (b) Rheumatoid arthritis in relatively early phase. (c) Rheumatoid arthritis, later phase, showing some "osteoarthritic" manifestations.

not only of cartilage but also of subjacent bone. Thus osteophytic articular margins are one of the characteristics of osteoarthritis.

Synovial thickening and effusion, with muscular atrophy, are relatively late

Pseudo-ankylosis

manifestations, so that when symptoms are first experienced by the patient, the disease has often reached an advanced stage radiologically. True bony ankylosis does not occur in this type of disease. Although limitation of joint movement may be extremely marked, it is due partly to muscular and other soft-tissue contractures and, in the severe cases, to the gross osteophytic outgrowths from the articular edges and to incongruity of the joint surfaces.



FIG. 166.—Arthritis of knee-joint. Osteoarthritis secondary to old genu valgum deformity.

Intra-articular formation of loose bodies.—Loose fragments, generally composed of cartilage with or without bone, may be found in joint cavities and are of varying pathological origin, as follows.

Meniscal or other cartilage disc fragments, especially in the knee.

Osteochondritis dissecans; especially in the elbow and knee due to localized subchondral avascular necrosis and trauma.

Intra-articular fractures, for example of head of radius.

Detachment of osteophytes in osteoarthritis.

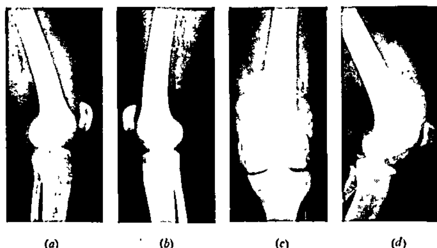
"*Melon seed*" *bodies* due to fibrinous deposits from chronic synovial inflammation.

Synovial osteochondromatosis, a proliferative lesion of the synovial membrane starting with the formation of multiple synovial villous fringes in the distal portions of which chondral and osteochondral nodules appear. The disease is a borderline condition presenting some neoplastic features.

All these lesions, though arising differently, have in common that the repeated mechanical irritation which the fragments cause between moving surfaces results in the development or aggravation of osteoarthritis. Such loose bodies when completely detached are often clinically very elusive ("joint mice").

4. OTHER FORMS OF JOINT DEGENERATION

There are other forms of joint disturbance having features resembling those of primary arthritis. They are seen as secondary phenomena complicating other lesions as, for example, Sudeck's atrophy of the carpal or tarsal joints, Volkmann's ischaemia, the joint disturbances of peripheral nerve injuries, and the neurotrophic lesions of tabes dorsalis and syringomyelia. All display



(a) (b) (c) (d)

FIG. 167.—Mono-articular proliferative arthritis treated by synovectomy. (*a*) Left knee showing suprapatella synovial thickening. (*b*) Right (unaffected) knee for comparison. (*c*) and (*d*) Left knee after injection with radio-opaque material (Pylumbrin).

a neurovascular disturbance, and are of interest in considering the aetiology of rheumatoid arthritis and osteoarthritis, as well as periarticular lesions such as subacromial bursitis.

5. CLINICAL FEATURES

(1) Rheumatoid arthritis

The disease progresses through the following stages: (a) prodromal, (b) acute, (c) chronic, (d) residual.

All too frequently the surgeon first sees the patient as a cripple with multiple bilateral deformities and contractures, with painful fusiform swellings of joints, muscular wasting, cold clammy extremities and secondary anaemia. This is a late stage of a disease which commences with a vague general illness, little more perhaps than chronic malaise and fatigability, with joint and muscle pains and indefinite chronic infection or metabolic disorder. The first sign may be nothing more than a fusiform swelling of an interphalangeal joint. From these beginnings the disease seems to take an almost inexorable course, extending from the hands to the wrists, elbows and shoulders, and from the knees to the feet and hips. Besides early wasting of muscles, the skin over the fusiform joint swellings becomes thin and shiny, the joints have increased warmth, are very sensitive to touch, and are painful on movement.

Early signs and symptoms

Deterioration may be rapid and aggravated by anxiety, by economic stress, by the inability to maintain general activity and by the lowering of respiratory

Deterioration

vital capacity due to the posture assumed and the lowered physiological demands. Disability is increased by the development of deformities during the progress of the disease. These deformities, readily correctable at first, become fixed, and are complicated by the development of structural changes in bone and soft tissue. The intensity of the signs presented in the joints tends to fluctuate. The chronic stage is followed by one relatively inactive or residual when the disease has *more or less burnt itself out* and joints have developed fibrous or bony ankylosis, or in which some measure of spontaneous recovery has taken place. Relapses into the preceding stage still may occur, but often *with diminishing frequency* and extent, though by this time the individual may have become severely crippled. The evidences of activity are usually clear enough clinically, but may be supplemented by regular reports of the erythrocyte sedimentation rate.

Deformities

Stage of relative inactivity



FIG. 168.—Arthritis of ankle and tarsus. Rheumatoid arthritis, showing patchy areas of decalcification, joint narrowing and marginal absorption, with pes planus.

(2) *Osteoarthritis*

While there are polyarticular forms of this disease which may start in the hands or in the knees, and may be associated with the menopause or with senility, it is more often *oligo-articular* and affects those joints subject to special stress, for example those of the spine and hips. As already stated, it is particularly liable to develop in a joint *repeatedly irritated* by some pre-existing mechanical defect and therefore may be monarticular. Any previous *polyarticular disease* of the infective or rheumatoid types may, for the same reason, show later osteoarthritic manifestations, but generally such changes are *completely* overshadowed by the other disease.

Combined lesions

As compared with rheumatoid arthritis, osteoarthritis is less malignant in its effects, is slower in development and usually later in age of onset, excepting that after trauma it may arise at any time. The symptoms vary in intensity. They are *pain, stiffness*, weakness and deformity, and joint friction, but disturbance of muscular function overshadows everything. *Pain*, though rarely intense, is often *disabling on account of its continuity* and aggravation by movement. Usually it is relieved by rest. In some cases, however, in which

Cause of symptoms

synovial irritation is marked, throbbing pain at night may be troublesome. Pain is frequently distributed to parts distant from the affected joint. This is due partly to reference in areas of the same segmental innervation, and partly to muscle spasm, muscular atrophy and fatigue.

Stiffness is not due entirely to bony malformation. Capsular and periarticular fibrosis and the degenerative changes in muscle play their part. The loss of movement is frequently limited only in certain directions, others being quite free. *Deformity* in osteoarthritis, as in most other forms of arthritis, is generally in the direction of flexion; it is initiated by unbalanced muscular action. *Weakness* is also mainly due to muscular wasting.

6. CAUSES OF DEFORMITY

The true deformities of arthritis are late manifestations of the disease, and should not be confused with the condition commonly called deformity, in which there is merely a contracture of the soft tissues limiting movement, but in which the joint position is within its normal range. The influences which combine in varying degree to cause deformity are:

(i) Atrophy of muscles with spasm of their antagonists and consequent imbalance.

(ii) Softening and stretching of joint capsules and ligaments and, later, fibrosis and contracture.

(iii) Destruction of articular surfaces.

(iv) Influence of gravity.

Deformity in polyarticular arthritis

In the hands, these factors are responsible for the flexion and forward subluxation of the proximal phalanges, ulnar deviation of the digits and flexion or hyperextension deformities of the interphalangeal joints. The wrists assume flexion, as do the elbows. Gravity plays no part in determining the position of the elbow, but in the shoulder it is the predominating influence in maintaining adduction. In the feet, wasting of the intrinsic muscles is the cause of clawing of the toes with resulting depression of, and undue pressure upon, the metatarsal heads. Deformity in the hips occurs relatively late in the disease; here flexion deformity is largely due to muscular contracture aided by the habitual sitting position.

7. RADIOGRAPHIC FEATURES

Decalcification

In rheumatoid arthritis the radiographic appearances are those of atrophy of the bone elements. The cortex of the bone ends appears thin and there is a more open texture of cancellous tissue. At first these changes are patchy but later the whole bone ends assume a uniform lessened density. Special technique may demonstrate the soft-tissue shadow of synovial thickening. In the more advanced cases there is reduction of joint space, patchy loss of articular cortical outline, and frequently more extensive destruction of the articular margins. All of these appearances are, radiologically, not unlike those of early tuberculous arthritis.

Hypertrophy

In osteoarthritis the narrowing of joint space is characteristically associated with increased density of bone shadow on the opposing surfaces. This reaction of sclerosis extends deeply into the articular ends, often leaving areas of lessened density producing "cystic" appearances. At the periphery of the

articular surfaces osteophytic projections are usually visible. The shadow of these projections is less extensive than the cartilaginous covering, which is radiotransparent.

8. TREATMENT

(1) General

Environment in prevention and treatment

This must largely concern itself with environment, with the social conditions providing the background of the sufferer, and also with the provision of the most suitable environment for institutional care when this is necessary. When possible, improvement must be provided in general hygiene, housing and industrial conditions, in nutrition, and in psychological well-being. The search for, and treatment of, dietetic deficiency, metabolic errors, and infective and toxic disorders, must be carried out under institutional conditions in which full investigative facilities can be co-ordinated with medical, physical and surgical treatment, including after-care, in an atmosphere of encouragement.

Such institutions or departments require special planning, staff and equipment. Team work is necessary. The leadership of the team should have a predominantly medical bias during the earlier stages of treatment. Accurate records are an essential for both diagnosis and treatment.

Psychological effects

In general treatment emphasis should be laid upon psychological factors. Fatigue and anxiety may easily aggravate or accelerate pathological processes and retard recovery.

(2) Special

As the ultimate cause of this disease is still unknown, all special treatment is either basically empirical or is directed to its local effects.

(a) Medication and vaccines

Aurotherapy

The use of autogenous or stock vaccines, or of gold and other heavy metals, is empirical. Neither these nor the local treatment of focal infection, however beneficial, can be regarded as specific. Nevertheless, the controlled administration of gold salts by intramuscular injection has shown convincing results. Equally enthusiastic are the advocates of vaccine therapy. For the details of these treatments, special reference must be made to works upon internal medicine.

(b) Physical and surgical methods

Local

(i) *Physical treatment.*—This is both general and local. The general type, strictly speaking, is gymnastic, and is directed mainly to the improvement of the functions of respiration, cardiovascular circulation and digestion. Local physical therapy by the use of irradiation, ranging from x-rays to infra-red rays, and by "massage", aims at the resolution of pathological processes, and the removal of the products of inflammatory reaction. The electrical stimulation of muscles and graduated activity of muscles and joints are directed to the restoration of normal physiological activity. Occupational therapy is an important adjunct to physical treatment. All these measures contribute to the relief of pain, which itself is an important guide in the control of this treatment.

Rest

(ii) *Orthopaedic treatment.*—This is primarily the p[illegible] of rest in

physiological positions, so as to control the mechanical background. Upon this, medical, physical and operative treatment are added as indicated.

(iii) *Operative treatment.*—This includes the manipulative procedures, used for the correction of deformity and the restoration of movement, as well as the open operations conducted *for the relief of pain, correction of deformity,* restoration of movement and relief of instability. *Surgery*

(c) *Application to particular types and to stages of activity*

The treatment of chronic arthritis, as classified at the beginning of this section, involves consideration of the greater part of the surgery of the locomotor system. The special treatment of chronic polyarticular arthritis, of either rheumatoid or more clearly infective types, in the acute or subacute stages, is *rest.* *Rest*

When activity is quiescent, the graduation of function must be initiated under carefully controlled conditions. In the chronic stages of arthritic disease, the mobilization of stiff joints and the correction of deformity may be initiated by manipulative means. Operative surgery should be required only when an adequate response has not been gained from preceding conservative measures, but correction of deformity may necessitate open operation. This is so for joints in which there is severe articular damage, and when there is ankylosis in a bad position. If the correction of deformity by plaster-of-Paris methods or by manipulation is not likely to be successful, capsulotomy may be indicated should a skiagram suggest that full correction can thus be obtained. When bony ankylosis is present, osteotomy through or in the neighbourhood of the old joint line will permit of correction. When the ankylosis is fibrous, removal of a suitable wedge at the joint line will permit both correction of deformity and production of bony fusion. The correction of deformity is also one of the objects frequently achieved in the operation of arthrodesis, the primary indication for which may be intractable pain. Arthrodesis also may be the means of achieving stability in defective joints, such as those which may be encountered after severe intra-articular injury, or those few arthropathies seen, for example, in tabes dorsalis. *Mobilization* *Surgery*

The scope of surgery in the restoration of movement is at present limited. This is a matter which is discussed below under the title, Arthroplasty.

Differing mechanical problems are brought to the surgeon by the requirements of the upper, as compared with the lower, extremity, and by the particular joints in each extremity. While many of these regional requirements are dealt with in the immediately succeeding paragraphs on physiological control, special sections of this work deal with the spine, the knee and the foot.

9. PHYSIOLOGICAL CONTROL IN TREATMENT

Physiological rest, as we understand it today, is a controlled process giving *immobilization* of part, or the whole, of the body in the position most favourable for the biological processes of growth and repair, while safeguarding functional restoration. *Physiological rest*

Physiological rest is not necessarily absolute or uninterrupted rest, though for some period it may be so. Its purposes are to promote healing by reducing the local physiological demands of the limb, by avoiding the aggravation of

OPTIMAL POSITIONS FOR TREATMENT OF ARTHRITIC JOINTS

JOINT	POSITION	REMARKS
Shoulder	Abduction 45° Flexion 30° External rotation 15°	Prevents stiffness in adduction, aids deltoid function, safeguards capsular integrity. The position is favourable for function in ankylosis
Elbow	Extension to about 100°	Safeguards the function of the elbow flexor muscles. If ankylosis is likely to occur, modifications of the position recommended must be made according to the wishes of the patient, guided by his social circumstances and occupation. When both elbows are involved, one should be treated at a smaller angle
Forearm	Mid prone-supine position	Favours the restoration of either movement. If ankylosis occurs, compensation for loss of pronation can be gained by abduction of the shoulder. Stiffness in supination is *objectionable*
Wrist	Extension 30°	The angle is measured upon the dorsum of the radius and of the third metacarpal
Digits and thumb	All joints flexed about 25°. Abducted and opposed moderately	The hand as a unit is held in the position of semi-grasp. The thumb practically continues the line of the lateral border of the radius. The phalanges of all digits are in the position of natural relaxation, i.e. that assumed when the normal hand is loose at the side of the body. Capsular and ligamentous stretching is avoided. The vicious position of metacarpo-phalangeal hyperextension is avoided
Spine	Normal curves maintained	Flexion as well as lordosis of the lumbar spine to be avoided
Hip	Abduction only sufficient in amount to compensate for true shortening. Rotation, *nil*. Flexion, 20°	In arthritis extreme degrees of true shortening of a lower extremity are unlikely to be found. Flexion permits sitting if there is compensatory movement in the lumbar spine
Knee	Flexion 15°	Avoids posterior capsular stretching and resultant hyperextension instability. The competence of the quadriceps is adequately safeguarded
Ankle	Right angle	If ankylosis appears inevitable the foot should be plantar flexed 5° to 10° in men, and a few degrees more in women to facilitate walking in heeled shoes
Tarsal joints	*Neutral as to inversion or* eversion	*While the arches of the* foot should be preserved, it is better, should ankylosis be inevitable, to err in the direction of eversion, for the weight-bearing surface exposed to the ground is less likely to be troublesome than if the foot is inverted or cavoid
Toes	Maintain flexion of M.T.P. joints and extensions of I.P. joints	Preserves intrinsic muscular activity ; avoids metatarso-phalangeal *subluxation* and metatarsal pressure points

pathological processes, and by bringing to bear upon the lesion the whole general metabolic resources of the patient.

It must be arranged so as to prevent the deforming influences of uncontrolled or unbalanced muscular activity, of muscular atrophy and of gravity. Relaxation and restriction of muscular activity are modified according to the type of disease. In some conditions, rest will alternate rhythmically with movement, the relation of one varying inversely with that of the other as healing proceeds. While, on the one hand, pathological conditions are being relieved by rest, *on the other hand no extrinsic pathological factors* should be introduced. Local treatment must be planned within the most favourable general background for physical and psychological health.

Immobilization

While joints are acutely inflamed the most perfect immobilization is necessary, and must be carried out until the inflammatory process has subsided and muscle spasm is relieved. The subsidence of pain and diminution of local tenderness, swelling and irritability are important guides. Defects in the application of rest are due first, to not giving adequate attention to the posture in which the joint is placed; secondly, to not guarding against the ill effects of movement, friction, pressure, constriction, traction and gravity; thirdly to imperfect timing of the duration or modification of rest and, consequently, failure to safeguard the maintenance or restoration of function when permissible.

Both for therapeutic physiological rest, as stated, as well as for the restoration of maximal usefulness should the affected joint become fixed by disease, arthritic joints should be immobilized in the positions shown in the Table.

During the chronic stages of arthritic disease, rest may still form a very important accompaniment of whatever other treatment is given. Here, however, there may be the added need of correcting deformity. Finally, rest may be used with the definite object of obtaining complete fixation or ankylosis of a joint—an objective, of course, which may be aided by surgical means.

10. ORTHOPAEDIC APPLIANCES

(1) Purposes of appliances

Appliances are used for the following purposes:

(i) Support; to oppose gravity.

(ii) Immobilization, or limitation of movement.

(iii) Correction of deformity.

(iv) Mobilization of joints.

(v) Substitution of defective muscular action.

Appliances must be designed so as to fulfil these purposes with maximal comfort and convenience. This involves lightness and accessibility, smoothness of anatomical fit with adequate strength, simplicity of construction, and economical and speedy manufacture.

Importance of good plaster technique

Makeshift appliances are harmful. There should be no excuse for the application of second-hand appliances. Good plaster-of-Paris technique has made this unnecessary. Indeed, for most short-term requirements plaster of Paris properly applied provides the most readily available instrument of physiological rest.

There is great variety in the design of appliances and in the modifications used by individual surgeons. Naturally, the methods of the author are emphasized but a few basic appliances are described which are founded mainly upon the inventions of many other workers.

(2) Littler-Jones shoulder abduction splint

This type of aeroplane splint is shaped to preserve an anterior position (flexion) for the upper arm in relation to the trunk, and therefore is not interchangeable for the two sides of the body. By means of a slotted and curved backward projection from the forearm piece at the elbow, a good range of external rotation may be given to the shoulder. The framework for the trunk and upper arm is made from one piece of mild-steel wire ($\frac{5}{16}$ inch thick) bent to form a half ring, suitably padded, or is attached to a shaped malleable metal band round the trunk above the iliac crest. At the front and back midline it bends at a right angle vertically to the level of the manubrium sterni, where it is again bent laterally to the front and back of the shoulder, then inclined somewhat downwards (45° to 60°) both ends meeting at the elbow to form a small loop which will hold a $\frac{1}{4}$-inch bolt. To this is attached (and held by a winged nut) the curved slotted portion of the forearm support which has a malleable gutter (felt-lined) and an adjustable hand-grip.

(3) Splints for hand

In many ways the hand is at last receiving better care, particularly in fractures, wounds, burns and peripheral nerve injuries. The lessons from these fields should with modifications be applied to the treatment of arthritis. Various first-aid appliances of sheet metal are available but none so far produced is satisfactory. In acute lesions of the interphalangeal joints each digit has its own problems and must be treated individually. Plaster of Paris, which still supplies the most satisfactory material for immediate support, requires precision in application. This should have as much care devoted to it as a surgeon would expect to give to the application of a plaster jacket for fracture of the spine. The physiological position for the hand, and a plaster splint with careful interdigital moulding, will give some measure of individuality to the digits.

Plaster moulds

The problems of arthritis in the less acute states bear certain resemblances to the problems seen in peripheral nerve and vascular injuries in which stiffness and deformation occur, the latter largely due to defective muscle balance and capsular contracture.

Many of the appliances used for nerve lesions are applicable to the arthritic hand. A great deal of ingenuity has been devoted to this matter by many workers. Yet appliances are often cumbersome and over-elaborate and, furthermore, defeat the object intended, which is to make the hand more useful. It is wise to keep the palmar aspects of the hand and wrist free for tactile appreciation. Flexibility and usefulness are aided by the use of springs. A serviceable type of spring appliance is that introduced for radial nerve palsy by Brian Thomas (1944).

Palmar aspects free

Springs

(4) Moulded leather or plastic splints

A common version is described, such as that used in cases of osteoarthritis of the first carpo-metacarpal joint and wrist. A lead or concrete model of the

forearm and hand is made from a negative mould. The latter is made as follows.

Negative moulds and positive casts

The area is greased with paraffin jelly and a thin malleable metal strip or tough webbing strap is laid along the dorsal surface of the forearm and hand. Wet plaster bandages are applied direct to the skin of the forearm, and on to the hand and thumb in the desired position. When nearly set, the plaster is split along the line of the protective strip and along the side of the thumb, and is removed from the limb. The edges are brought together, and bound by an encircling plaster bandage, which should also pass over the distal end to seal it off.

When completely dry, the negative mould is buried hand downwards in a trough of sand with just the upper end of the mould exposed. The sand is pressed well down all round it, and then the mould is filled with molten lead; into the centre of this a steel rod is thrust which, when the lead has cast solid, can be used for the manipulation of the cast, and for its control in a vice when the leather mould is fashioned. A piece of dry-tanned " butt " or "shoulder" leather, which has been thoroughly soaked in cold water to soften it, is then applied and shaped by stretching, pressure and hammering upon the cast in such a way that the opening for future lacing will lie along the dorsal midline of the limb. Special moulding and stitching will be required in the cleft between the thumb and index finger. When the leather has dried, it is removed from the lead cast and is ready for rough fitting which, like all appliance fitting, should be supervised by the surgeon. The latter marks on the leather which parts can be cut away, and at which points easing of pressure may be required. The splint is then finished off by the maker. It is polished, the edges smoothed, " eyes " are fitted for lacing and, if necessary, a reinforcing metal strip of duralumin is shaped and attached to the palmar aspect of the wrist.

Perspex splints

Leather splints thus prepared are suitable for the elbow and for the knee, when it is desired to have a light, accurately fitting, easily removed appliance of greater durability than plaster of Paris. Similarly, splints made of synthetic plastics such as Perspex can be prepared. This material is obtainable in sheets of various thicknesses. It becomes plastic when heated, and then can be moulded under pressure upon a positive cast or into a negative mould. Some very satisfactory small splints may be fashioned by hand pressure and the use of a low-temperature Bunsen burner.

(5) Thomas's caliper and modifications

A classical splint and its evolution

The Thomas bed knee splint, the fundamental appliance upon which so many different instruments for the lower extremity have been based, was at an early stage modified by its inventor so as to provide a convalescent splint for the ambulant patient. It was thus used as a weight-relieving and immobilizing splint; for the former purpose it has a specially shaped ring differing from that used in the bed splint. In arthritic patients its greatest sphere of usefulness is for osteoarthritis of the knee. For the arthritic hips of old people, in whom pain on weight-bearing is a prominent feature, it has a certain place; but the patient's mental make-up needs careful judgement before ordering the splint, as undoubtedly it is somewhat irksome to wear, and many older people are not very tolerant.

Weight-bearing ring

In its simplest form the uprights are made of mild-steel rod, $\frac{3}{8}$-inch thick, and at the lower end are bent at a right angle and shaped to fit into a tube of $\frac{1}{4}$ inch diameter, penetrating the heel horizontally. A strap of leather passes round the leg and uprights above the ankle; a broad band of leather, about 4 inches wide, passes between the uprights behind the knee so as to control this joint in a few degrees of flexion, a shaped leather knee-cap being fitted in front. At the upper end the padded leather-covered ring is attached to the uprights a little way behind the mid point of its circumference, and the back part of this is somewhat flattened. The ring is attached obliquely to the uprights, being higher on the outer side. It is also lower under the tuberosity of the ischium than it is in front of the thigh. The fit below the tuberosity of the ischium is most important if the splint is to bear weight comfortably, and is a point in which a large number of calipers are defective. In children, the caliper is made with adjustable extension pieces at the lower end, which by elongation will allow for growth.

Half-ring caliper

A valuable modification of this appliance is provided by an incomplete metal ring in which the front section is closed by an adjustable leather strap and buckle. This has certain advantages, particularly for the arthritic patient who might find difficulty in adjusting the complete-ring caliper because it has to be threaded over the foot, ankle and knee. The half-ring caliper is indented under the ischial tuberosity and thus gives perfect adjustment.

Knee movement for caliper

Another valuable modification of the caliper is the provision of jointed uprights for movement of the knee, which may be locked, if desired, in full extension. Such an appliance is expensive, for its manufacture requires expert craftsmanship. It is suitable for prolonged use and adds to the patient's comfort and convenience in sitting.

(6) Plaster of Paris for knee

Special emphasis is needed, for plaster of Paris well applied is of immense value in this region. There are two forms, as follows:

Guarding plaster

(i) The guarding plaster, applied from the groin to the ankle with the knee in almost complete extension, carefully moulded over the bony points and arranged for splitting on each side to form a bivalve splint, generally at the end of 10 to 14 days in relatively acute lesions. There are those who advocate the use of unpadded plaster for this work. Provided that the lining of the plaster is not exuberant, there are some advantages in using a thin layer of cellulose bandage or stockinet next to the skin.

Wedging plaster

(ii) The second form is the type of plaster used for the correction of deformity; it is named in America after its inventor, Lovett (*see* Fig. 169). A similar extent of plaster of Paris is applied over a thin lining after maximal correction has been obtained by simple stretching manually. Three particular points have extra padding, points at which special pressure will be liable to come; these are behind the thigh at the upper end, in front of the patella, and behind the tendo Achillis at the lower end. After the plaster is dry an almost circumferential saw-cut is made around the sides and back of the plaster from one side of the patella to the other. Into this saw-cut are inserted blocks of wood, which are increased daily until the plaster breaks across the front. It may be necessary to repeat this several times before full correction is achieved. Pain in front of the patella is an indication that treatment is too vigorous. If it does not pass off quickly, the wedge last applied must be removed. Correction of deformity by this means has an advantage over the use of traction or inclined planes in bed: it does permit of greater freedom of movement by the patient as a whole; it is less painful and is quicker.

(7) Compression bandage for knee

This is useful in the treatment of any acute synovial effusion of the knee and for the post-operative care of knee-joint operations to control swelling. Three layers of wool are successively bandaged over the whole limb from the ankle

to the groin while the limb is held in the elevated position. The wool, of loose texture and medium thickness, is evenly spread. The first layer is covered by a firmly applied domette bandage 3 inches wide. Each successive layer is bandaged more firmly. It is important to stress even application, for any local constrictions would defeat the end, which is to obtain an equal capillary compression throughout the limb.

Capillary compression in control of synovial effusions



(a)



(b)



(c)



(d)



(e)

FIG. 169.—Correction of flexion deformity of knee by plaster method. (*a*) At the commencement. (*b*) Padding at chief pressure points. (*c*) The plaster applied and marked for cutting. (*d*) Opening the cut (patient on his face). (*e*) Insertion of wood block.

(8) Short caliper for foot

This splint cannot relieve body weight; its purpose is to limit lateral strains. While single inside or outside irons may be used, for most arthritic conditions of the tarsal joints it is better to order a double iron, both uprights of which are joined by a metal half-ring of flat spring steel (leather covered) at the back of the upper calf and completed in front by a leather strap with buckle. This ring is placed at the level of the tuberosity of the tibia and of the head of the fibula. The lower ends of the uprights are inserted into a heel tube as in the Thomas caliper. T-straps are attached according to whether valgus or varus strains are being treated. In the former, the broad upright limb of the T is attached to the inner side of the shoe leather below the tibia, and the horizontal narrow limbs pass round the ankle and the outside iron. Both inside and outside T-straps may be used if desired.

(9) Dorsiflexion splint for foot

Extending the idea of splint flexibility, the author has developed a device for the treatment of the foot where limitation of plantar flexion of the ankle is desired, and some control of lateral movement in the tarsal joints. Spring-steel wires of No. 8 British Standard gauge are attached to a horizontal band of steel and leather at the level of the tibial tubercle, as in the former splint. These wires pass downwards on each side of the limb, and at the level of the ankle-joint are coiled once, and then pass onwards to the heel, into which they are bent backwards upon themselves into a suitably constructed box-shaped socket. If the direction of the coil at the ankle is reversed, the appliance is equally suitable for limiting dorsiflexion, but this is likely to be required only in patients with calf-muscle paralysis.

(10) Plaster of Paris for osteoarthritic hip

Plaster spica

A valuable method, which should be more often used, is the short plaster-of-Paris spica. It does not, of course, give complete immobilization, but many patients manage very well with it. By this means the more serious operative treatment of arthrodesis may often be avoided. A satisfactory method is to apply plaster over stockinet and thin cellulose lining with the patient in the standing position. It is carefully moulded over the bony points of the pelvis but does not extend much above the iliac crests. Below, it is finished over a felt pad around the thigh just above the patella. It is most helpful when fixed deformity is not a marked feature. Such treatment is used for a month or so and is then followed by physical therapy.

11. PHYSICAL TREATMENT

It is important that the clinician responsible for the general management of the case should appreciate the scope of physiotherapy, and should incorporate the physiotherapist fully in his team. Physical treatment includes radiant heat, paraffin-wax baths, hydrotherapy, electrical stimulation of muscles, massage and remedial gymnastics. In this field also belong ultra-short-wave and x-ray therapy. (*See* section on After-care.)

Posture training

(i) *Training in posture.*—Under remedial gymnastics, special emphasis must be laid on the active treatment of general posture and body mechanics during all phases of treatment. The clinician must constantly be on guard to prevent those vicious postures into which the chronic invalid is so prone to relapse. Active measures should be adopted following the methods of Goldthwaite of Boston (1945). Attention is first directed to respiratory and abdominal exercises in recumbency and conscious effort paid to the co-ordination of those muscle groups specially involved while freeing the central nervous system of the vast mass of reflex activity concerned in the maintenance of balance or in dynamic exercise. Such gymnastic activity is inclined to be tedious, and so must be directed by physiotherapists of character and enthusiasm. It is of importance equally for the bedridden and for the ambulant patient. As an aid in the treatment of general posture in arthritic subjects, the "Goldthwaite" brace (Fig. 170) is recommended.

(ii) *Remedial exercises for the restoration of joint function.*—Muscles which are atrophic will require faradic stimulation in the earlier stages. As soon

as voluntary contractions can be achieved they should be encouraged by purposeful effort. For this, movements should be graduated over a prolonged period under active control of the patient's muscles, with assistance; so easy is it in the early stages to stimulate the lower sensory reflex arc of pain with consequent inhibition of muscular activity. These active

Active supported exercises

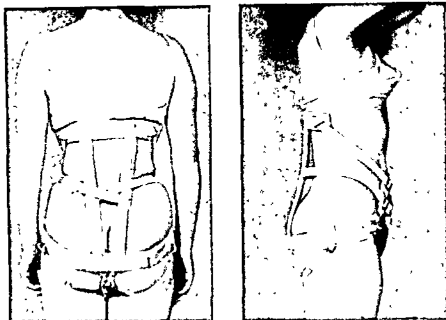


FIG. 170.—Goldthwaite's spinal brace.

supported movements should obviate pain. Jerky swinging movements are undesirable, and painful passive stretchings are objectionable.

(iii) *Occupational therapy*.—For arthritic patients there is great scope in this field. The restoration of freer movement in joints and the improvement of muscular action is enhanced if the interest of the patient can be projected upon jobs to be completed rather than upon the physical means involved.

12. MANIPULATIVE TREATMENT

(1) Rheumatoid arthritis

In rheumatoid arthritis special care must be taken in the application of manipulative force for two main reasons.

(i) The relative decalcification of the skeleton renders fracture more easily produced than in normal bones, or in osteoarthritis.

(ii) The stiffer the joint the greater the temptation there is to move it and the less beneficial the results.

Dangers

Besides the atrophic condition of bones, the soft tissues around the joints also are degenerate and so more vulnerable. The tearing of ligamentous or tendinous attachments produces a local interstitial haemorrhage, with connective-tissue proliferation akin to the fibroblastic and osteoblastic proliferation seen as a common complication of injuries in the region of the elbow-joint.

In spite of this, in carefully selected cases suitable manipulative measures are indicated. In applying such treatment the main principle to be followed is that where the range of movement is considerably restricted, the manipulations should be carried out fractionally, a small range being added each time, and the limb supported in suitable apparatus if gravity is likely to operate in opposition to the desired result. An important example of this is provided by the shoulder, in which the reactive changes in the periarticular tissues after even small manipulations may result in serious inhibitions of an already degenerate deltoid muscle when its function is necessary for a successful restoration of joint mobility. Furthermore, not only in the actual application of manipulative force but in the later re-education and maintenance of mobility, the idea of "coaxing" rather than forcing is to be followed. "Force" can be used where joints and muscles are only relatively subnormal. In re-education graduated active supported movements are better than active violence; passive painful movements are rarely desirable.

Fractional manipulation

Coaxing, not forcing

(2) Osteoarthritis

In osteoarthritis there are certain indications for manipulative treatment. The elements of atrophy are usually less marked so that tissues are more capable of withstanding manipulative force. Nevertheless, ill-directed force should not be applied; real violence may detach osteophytes or otherwise damage the articular contours. Slowly performed passive movements under good anaesthesia will overcome muscular contracture and stretch periarticular adhesions. Improvement of movement and relief of pain can often be achieved; but the result is dependent upon good post-operative physiotherapy and muscular re-education. The hip-joint provides a good example. A type which often justifies this treatment is the man or woman of between 50 and 60 years of age, who during a period of months has experienced increasing pain and stiffness and in whom the radiographic appearances are those of an osteoarthritic process of many years' duration.

Passive stretching in osteoarthritis

Neither in rheumatoid nor in osteoarthritic joints are the radiographic appearances a reliable guide in the selection of suitable joints for manipulative treatment. Joints which on the films appear to be hopeless may produce worthwhile results. Radiological appearances must be tempered by judgement based upon the clinical findings. *The chief contra-indication to manipulative treatment in any arthritic joint is the presence of an active inflammatory process.*

Radiography unreliable guide to prognosis

13. OPERATIVE SURGERY

The main purpose of the operative procedures to be discussed is to control the effects of the disease rather than the disease itself. Without exception the indications for their use arise only when the disease is in a quiescent state, and when there is inadequate response to the medical, physical and mechanical methods already discussed. Treatment under these headings will generally still be an important accompaniment of surgical intervention and after-treatment. The objects to be achieved by operative means are as follows:

(1) Objects

(i) *Relief of pain.*—Open operations for pain are most frequently required in osteoarthritis, the procedure adopted generally being arthrodesis, which is the production of conditions favourable to ankylosis. *Tavernier* of Lyons

describes operative procedures for the sensory denervation of joints and claims satisfactory improvement. He advocates such procedures as an adjunct to other operative methods such as arthrodesis and arthroplasty. Part of the benefit achieved by synovectomy is doubtless due to the same process.

(ii) *Correction of deformity.*—For contractures of muscles, and of joint capsules, soft-tissue operations may be sufficient, but they are often an accompaniment also of other procedures, such as osteotomy, wedge excision of joints or arthrodesis.

(iii) *Restoration of movement by open operation.*—This may also be aided by the division of contracted soft tissues, but operations upon the bony components of joints are frequently indicated; yet at present they have limited scope. The simplest of such procedures is cheilotomy, in which the bony excrescences (osteophytes) at the periphery of joint surfaces may be removed to improve movement, say, in one direction. An example is provided by the hip-joint, where this operation has not infrequently been done at the outer side of the acetabulum in order to improve the range of abduction. Though some successes have been reported, results are liable to be disappointing because of the incongruities of the rest of the articular components.

Cheilotomy

(iv) *Relief of instability.*—This is most commonly achieved by the operation of arthrodesis, but certain forms of osteotomy, as for example that advocated by McMurray (1943) for the hip-joint, have an important place.

(2) Operations upon non-osseous tissues

These include tenotomy, capsulotomy and synovectomy.

(*a*) *Tenotomy*

Usually this is an incident in the course of some other procedure such as manipulative correction of adduction deformity of the hip or of capsulotomy of the knee. In the former case, a tenotome is passed subcutaneously and lateral to the tendons of the adductor longus and adductor magnus at the upper end of the thigh close below their origin from the pubis—care being taken to avoid the saphenous vein. The sharp edge of the tenotome is applied medially against the tendons until it can be felt in the subcutaneous tissues.

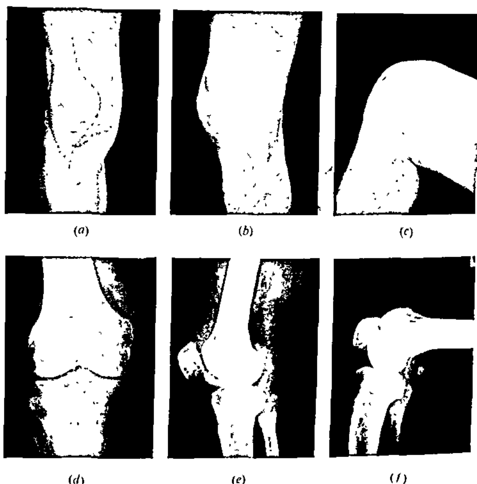
(*b*) *Capsulotomy*

This operation has limited scope. In a patient with a very severe flexion deformity of the knee-joint, which cannot be corrected in the earlier stages by mechanical measures, the operation sometimes will be necessary. A lateral incision is made on each side of the lower end of the thigh towards its posterior aspect. The posterior surface of the femur, deep to the popliteal vessels, is exposed between the hamstring tendons behind and the vastus medialis and vastus lateralis, respectively. Each of the three tendons is lengthened by an elongated Z-shaped incision. The posterior capsule and the posterior fibres of the medial collateral ligament are detached from the femur, after which it is possible to effect a considerable degree of extension of the knee if other conditions within the joint permit.

(*c*) *Synovectomy* (*Fig.* 171)

This means an extensive, though usually subtotal, removal of a synovial membrane in which there are persistent intractable proliferative changes associated with pain, and limitation of movement, particularly of extension. The best results are to be expected in monarticular synovial disease.

Nevertheless there are many examples of polyarticular disease of the rheumatoid type in which selected joints can be benefited. On the other hand, it should not be performed when the joint is in an acutely inflamed state, nor should it be left until severe deformity, gross destruction of the articular cartilage, or fibrous ankylosis has occurred. The knee is the joint which most commonly is treated in this way, but there is reason to believe that other joints could equally be helped by the removal of the whole of the synovial membrane upon the



(a) (b) (c)

(d) (e) (f)

Fig. 171.—Synovectomy of the knee for mono-articular proliferative arthritis; one year after operation. (*a*) Extent of scar. (*b*) and (*c*) Range of flexion. (*d*), (*e*) and (*f*) Radiographs of same positions; note in (*d*) the healed areas of marginal absorption.

extensor surface. This is a field in which further research is clearly needed.

Indications

The following reasons are offered for the operation.

(i) Sensory denervation of a large area of the joint.

(ii) Removal of a structure in which granulation tissue and proliferation cause exudation as well as increased secretion.

(iii) Removal of fringes which become nipped.

(iv) Opening of the joint area to vascular regeneration.

(v) To permit replacement with an adequate endothelial membrane.

Synovectomy should form part of the operative procedure *in arthrodesis*; further details of it are given below under arthrodesis of the knee.

(3) Osseous operations

(a) *Osteotomy*

Osteotomy is generally performed for the correction of deformity. It may, in addition, form part of the technique of arthrodesis (for example ischio-femoral arthrodesis of the hip).

Intertrochanteric osteotomy of the femur.—In the treatment of osteoarthritis of the hip-joint, this operation is associated with the name of McMurray, who applied the idea of the Lorenz bifurcation osteotomy for the purpose of altering the weight-bearing alignment of the upper end of the femur. It thus provides an excellent means of correcting deformity, while often preserving some movement in the joint.

Alteration of weight-bearing line

An incision is made along the anterior border of the tensor fasciae femoris muscle, and curving backwards through the muscle one inch below the lower prominence of the greater trochanter. The upper fibres of the vastus lateralis and vastus intermedius are stripped subperiosteally from the front and lateral sides of the femoral shaft. The finger, covered with surgeon's gauze, finds the lesser trochanter upon the inner side, and a curved metal guide or elevator is placed above it and against the inferior-medial surface of the femoral neck. The guide is retracted medially by an assistant, giving a good view of the site of osteotomy. A narrow osteotome is driven through the dense inner cortex of the femoral neck immediately above the lesser trochanter. A one-inch osteotome is then directed from the outer side of the femur ¾ inch below the greater trochanter obliquely upwards to the first osteotome, which has been retained in position. This technique minimizes the risk of splintering the inner aspect of the femur. The guide and narrow osteotome are now removed, and the broad osteotome is used as a lever to displace the upper end of the femoral shaft inwards under the acetabulum. Rotation, flexion and adduction deformity is corrected; the wound is sutured and a plaster-of-Paris spica is applied to include the whole of the limb on the affected side, together with the opposite thigh.

This technique is also suitable for a simple transverse or wedge osteotomy in the intertrochanteric or subtrochanteric region for the correction of deformity, if there is ankylosis of the hip-joint.

(b) *Arthrodesis*

Arthrodesis involves the production or completion of ankylosis by surgical means. In arthritis the indications for arthrodesis are:

Indications

(i) The relief of intractable pain
(ii) The control of instability
(iii) The correction of deformity
} in which the conservative measures already discussed have not been successful.

(iv) To dispense with external appliances otherwise necessary to achieve (i), (ii) and (iii). This often may be advisable in order to give the patient greater mental and physical freedom.

The procedure is more often indicated in the treatment of the patient with a single joint affected by osteoarthritis, especially of the traumatic type, and when, though stiffness may be very marked, the remaining few degrees of movement cause crippling pain. It is less often indicated in patients with generalized atrophic or rheumatoid joint diseases, the natural tendency of which is in the direction of ankylosis.

Arthrodesis is required more often in the weight-bearing joints of the lower extremity than in the upper extremity, where the mechanical conditions are different and the osteoarthritic changes are slighter.

Contra-indications

The contra-indications, apart from those associated with all surgical operations, are, first of all, found in the extent to which the end can be achieved by other measures such as rest, medicine and physical therapy. In addition, arthrodesis occasionally may be undesirable or incompatible with the state of the other joints, as, for example, in bilateral osteoarthritis coxae.

Methods

In certain joints (for example hip) both intra-articular and extra-articular methods are available. Whereas in tuberculosis the extra-articular method is desirable where possible, there is, in chronic arthritis, no objection to the surgical exposure of joints.

The essential achievement is the bony union in the optimal position of the elements comprising the articulation. It is well to remember that, by whatever method used, one merely provides the biological conditions within or around the joint which will be favourable for bony fusion. It seems important, therefore, that in a joint having a large synovial cavity (for example the knee) the operation, if intra-articular, should include wide excision of the synovial membrane, so as to facilitate the entrance of new vascular tissue to the bone-forming elements and to remove, as far as possible, the inhibitory effects of synovial fluid upon osteogenesis.

(i) *Hip* (Figs. 172, 173, 174).—Of the two chief methods available there is less indication for extra-articular grafting in chronic arthritis than there is for it in tuberculosis. In fact, there is some contra-indication provided by the fact that for the success of that method a much more complete and prolonged period of immobilization is required for the whole patient under institutional conditions—a feature which is particularly undesirable in the relatively aged. For unilateral osteoarthritis of the hip there is growing support for the method which combines an intra-articular operation with the use of a transfixation nail.

Intra-articular two-stage operation

Such is the method of Watson-Jones, in which, after excision of all the articular cartilage and cortical bone from the femoral head and acetabulum, the joint is fixed by an enlarged Smith-Petersen nail. The operation is performed in two stages. First, through the Smith-Petersen incision (*see* p. 403), the joint is exposed, its capsule widely opened and the femoral head dislocated (by flexion, adduction and external rotation) so as completely to expose the acetabulum. From both articular surfaces every vestige of cartilage is removed and the raw areas are broken up by multiple chisel and gouge cuts. The femoral head is then replaced and the wound closed.

Second stage

The second stage of the operation, in a fit patient, may be proceeded with immediately, but in the aged it can be delayed for two or three weeks. For this, the patient is fixed upon an orthopaedic table with slight traction in the neutral position and the two malleoli touching. It is important to prevent undue abduction of the hip-joint, a possible cause of post-operative low back pain. A Smith-Petersen nail of about 5 inches length is then passed through the femoral neck into the dense portion of the acetabular roof, under radiographic control. Antero-posterior radiography alone is adequate for there is a wide margin of error permissible in the sagittal plane. The passage of a cannulated nail over a guide pin is not recommended owing

Use of nail

to the risk of the pin being bent or broken in the onward passage of the nail and thus being driven into the pelvic cavity. During the operation an intravenous drip of saline or plasma is given, and afterwards a plaster-of-Paris spica is applied which extends well above the waist on the opposite side, and includes the knee in some flexion and the foot at a right angle. It is retained for from ten to twelve weeks but is gradually shortened, the

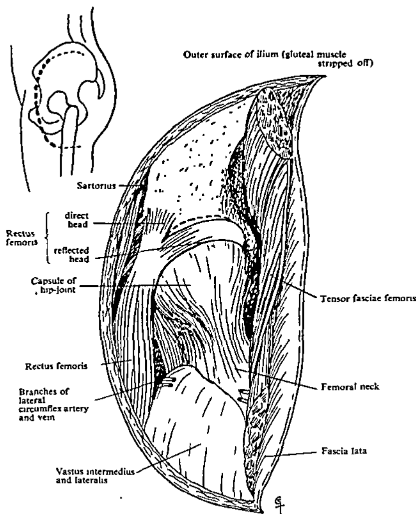


Fig. 172.—Arthrodesis of hip; exposure of hip-joint. Inset shows incision which may be extended backwards, above and below, if more room is needed.

foot piece being removed at four weeks when the patient may be allowed to start some weight-bearing on crutches. At the end of the second month the plaster may be removed from the knee-joint to permit movement. The great advantage of this method is the earlier ambulatory progress of the patient with assured fixation of the hip by the nail while bony consolidation is occurring—a process which in the method of graft arthrodesis may be delayed for some months, if it does not fail altogether.

Time in plaster

A successful arthrodesis of a single osteoarthritic hip is to the patient a matter of much satisfaction, owing to the loss of pain and to the disappearance

Advantages

of muscle spasm and anxiety. The relief and general mobility achieved by these means entirely outweigh the complete fixation of what is already a stiff and deformed joint. The gait appears almost normal and the chief remaining disability is the relatively minor one of difficulty in doing up the shoe laces. The compensatory mobility of the lumbar spine is usually sufficient to permit of a reasonable sitting position.

Ischio-femoral graft arthrodesis

Where an alternative method of arthrodesis of the hips is desirable, the ischio-femoral graft arthrodesis, as described by Brittain, is recommended. With similar precautions as to the position of fixation upon the orthopaedic table and for the combat of shock, the front and lateral surfaces of the inter-trochanteric region are exposed through a modified Smith-Petersen incision. The upper fibres of the vastus lateralis and the vastus intermedius are stripped subperiosteally downwards, and the inner side of the femoral neck is

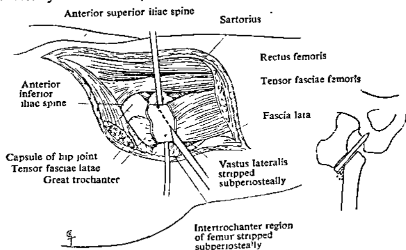


FIG. 173.—Intertrochanteric osteotomy; exposure suitable for ischio-femoral arthrodesis. Inset, shows position of ischio-femoral graft.

Inter-trochanteric osteotomy

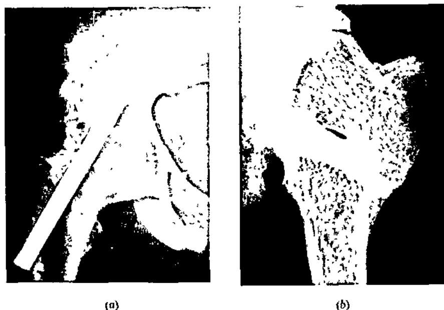
exposed. Immediately above the lesser trochanter a chisel cut is made through the cortical bone and an oblique osteotomy made with a broad chisel, aiming for this point but starting an inch below the lower prominence of the greater trochanter laterally. The osteotome or chisel is driven on into the region of the ischio-pubic junction immediately below the acetabulum, the direction being controlled by antero-posterior radiography. A second osteotome is then passed through the same gap, immediately above the first one, into the ischium so as to make a wider notch at the latter point. The necessity should be stressed of accurately siting the point of fixation of the graft high upon the ischium. Attempts to direct the graft into the region of the tuberosity of the ischium are dangerous, owing to the real risk of penetrating the sciatic nerve at this level. The first osteotome is removed, and along its path is inserted a massive graft which is prepared from the subcutaneous surface of the tibia. This is reinforced by cancellous chips from the tibial condyle. After this an opportunity is taken to correct any remaining rotational or adduction deformity, care being taken to avoid undue abduction. The wounds are then closed, and a double plaster-of-Paris spica is applied, which will include the whole of the lower extremity on the affected side and the thigh on the opposite side. This will remain for two months in this form, but the thigh-piece on

Directing graft into ischium

the opposite side can then be removed and the patient may be allowed to stand on the affected side, and gradually to walk with the aid of crutches, by which time the plaster may be removed from the foot. In this state, fixation should be retained for a further two months; it may be required for longer. *Union slow*

While the longer convalescence after this operation is not undesirable in tuberculosis, for which it was particularly designed, in senile osteoarthritis it is quite clearly objectionable.

Other methods of arthrodesis include a single intra-articular fusion as described in the first stage of the Watson-Jones operation, and the older extra-



(*a*) (*b*)

Fig. 174.—Arthrodesis of hip. (*a*) Watson-Jones two-stage method (one year after operation). (*b*) Ischio-femoral type for arthritis secondary to congenital subluxation (one year after operation).

articular ilio-femoral graft methods of Hibbs and Albee, none of which are recommended for arthritis.

(ii) *Knee* (Figs. 175 to 180).—This operation is indicated for intractable osteoarthritis, particularly of the traumatic type which is prone to be associated with deformity and instability as well as with pain and weakness.

A long midline incision is made, which at the patella curves slightly round its medial border. The incision extends for three inches or so above the patella and downwards for two inches below the tibial tubercle. The periosteum is stripped off the front of the tibial condyles and neighbouring portion of the tibial subcutaneous border, including the tubercle and patellar ligament. The quadriceps expansion is divided from the medial border of the patella and the rectus femoris is incised in the midline. The whole synovial membrane is dissected from the anterior compartment of the joint together with the infrapatellar fat pads. In order to complete this stage it is necessary to dislocate the patella laterally and to rotate it through 180° on its long axis. The cartilage and cortical bone is completely removed from all the articular surfaces and the remains of the menisci are extracted. The *Technique* *Approach as in synovector*

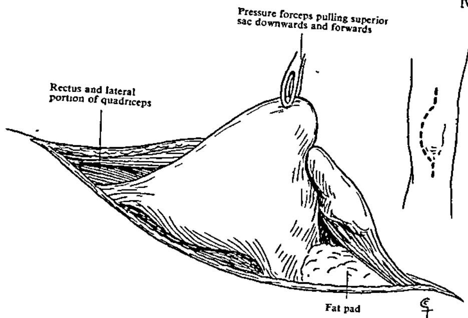


FIG. 175.—Arthrodesis of left knee. First stage, showing dissection of synovial membrane prior to synovectomy. Inset shows line of incision.

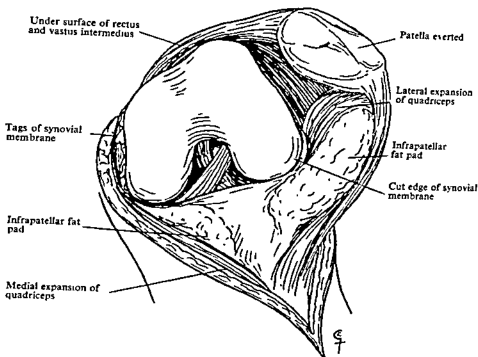


FIG. 176.—Arthrodesis of left knee. First stage, after synovectomy.

rawed bone surfaces are then extensively chipped up with a gouge or chisel. Soft cancellous chips are packed into the remaining spaces and a bone graft, prepared from the exposed portion of the anterior surface of the tibia, is turned round and the lower sharp extremity driven upwards into a prepared hole in the femoral intercondylar region; the other end is replaced in the

upper extremity of the tibial groove from which the graft was removed. The denuded patella is replaced, the quadriceps sutured and the wound closed. This operation is usually performed through an exsanguinated field produced by the application of an Esmarch tourniquet. After operation, a plaster-of-Paris spica is applied with the knee in 15° flexion and including the foot at a right angle. Owing to the dangers of reactive hyperaemia, some surgeons prefer to apply a pressure bandage throughout the whole limb, and to put on the plaster spica about a week later. If this procedure is followed the limb should be supported after operation upon a well-applied Thomas's leg splint suitably elevated. If the plaster is applied immediately, proper precaution must be taken to safeguard the circulation of the limb and to deal with post-operative swelling, should it occur.

Tourniquet

Plaster spica

After-care

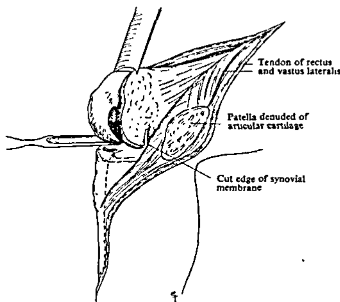


FIG. 177.—Arthrodesis of left knee. Second stage, removal of articular cartilage and cortical bone.

(iii) *Ankle* (Fig. 181).—This is indicated particularly for traumatic osteo-arthritis which is the result of a malunited Pott's fracture-dislocation. The classical exposure of this joint through an antero-lateral incision is quite straightforward. The removal of the articular cartilage and the preparation of the bony surfaces are facilitated by first turning down the lateral malleolus after osteotomy of the lower end of the fibula. Thorough chipping of the opposed surface of the tibia, talus and fibula, is followed by sliding a graft, prepared from the anterior surface of the tibia, downwards into a pit cut into the upper surface of the talus. Position desired: 5° to 10° plantar flexion.

(iv) *Triple tarsal* (*see Foot, Surgery of*).

(v) *Toes* (*see Foot, Surgery of*).

(vi) *Spine.*—This operation is indicated in the more localized forms of spinal osteoarthritis, particularly of the traumatic type after fractures, and other injuries of the vertebral bodies or that associated with spondylolisthesis. For further details the reader is referred to the chapters dealing with the spine and with bone grafting.

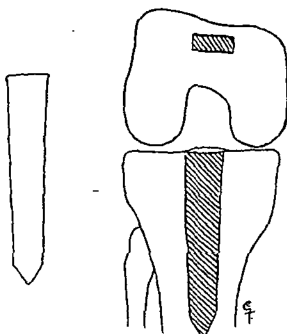


FIG. 178.—Arthrodesis of right knee. Preparation of tibial graft and of femoral bed (diagrammatic).

(vii) *Wrist* (*Fig.* 182).—This operation is commonly required for intractable symptoms due to osteoarthritis following intra-articular injuries, for example ununited fracture of the carpal scaphoid.

A midline dorsal incision is made extending three inches above the wrist-joint and downwards to the distal edge of the capitate bone. Large subcutaneous veins crossing the wound are divided and ligatured. The deep fascia is opened and the dorsal carpal ligament divided between the tendons of the extensor pollicis longus and the extensor digitorum. The dorsal surfaces of the radius and carpus are stripped subperiosteally and the capsule of the wrist-joint is opened. After the articular surfaces of the radius, the scaphoid and the lunate bones have been denuded of cartilage, a bone graft about three inches long and half an inch wide is cut from the exposed surface of the radius, and turned round, and the sharp upper end is driven into a hole made in the capitate bone.

The dorsal carpal ligament is sutured and the wound closed. A well-padded plaster cast is applied with the wrist in 30° of extension. It is cut down to the padding at once, and is renewed in two weeks when post-operative swelling has subsided.

(viii) *Shoulder and elbow*.—These operations are less often required in arthritic conditions. In the elbow, a similar method may be used as for the knee, a graft taken from the olecranon and subcutaneous surface of the ulna being rotated and driven across the joint into the humerus after the articular cartilage has been removed. In order to preserve

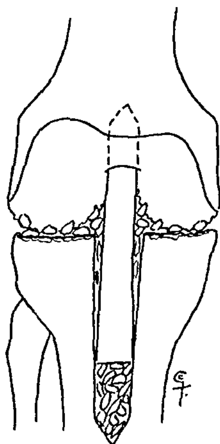
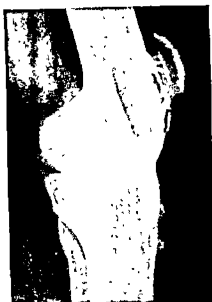
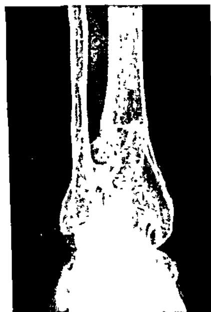


FIG. 179.—Arthrodesis of right knee. Final stage, placement of tibial grafts and cancellous chips (diagrammatic).


(a)


(b)

FIG. 180.—Arthrodesis of knee. (a) and (b) Incorporation of single long cancellous graft, with thin cortical covering, removed from upper end of tibia.



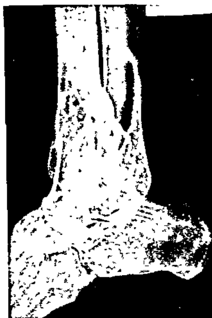


FIG. 181.—Arthrodesis of ankle. Note low angle of fixation for walking with heeled shoe.

pronation and supination movements it is advisable also to excise the head of the radius.

In the shoulder, the approach may be through the delto-pectoral interval and the anterior fibres of the deltoid turned downwards. After the removal of articular cartilage from the humeral head and glenoid cavity, the bone may

be fused to the latter by driving a short Smith-Petersen nail through both bones. Alternatively, screws may be passed into the humeral head from the acromion, the inferior surface of which is denuded. Brittain has advocated the use of a tibial bone graft to bridge the gap between the humerus and the axillary border of the scapula. For this purpose a posterior approach is made. In the author's experience some of these grafts have been absorbed at their middle.

(*c*) *Wedge excision of joints*

In joints with bony ankylosis in a deformed position, wedge osteotomy through the joint line will enable the deformity to be corrected, the new position being retained in plaster or other suitable appliance. The same procedure

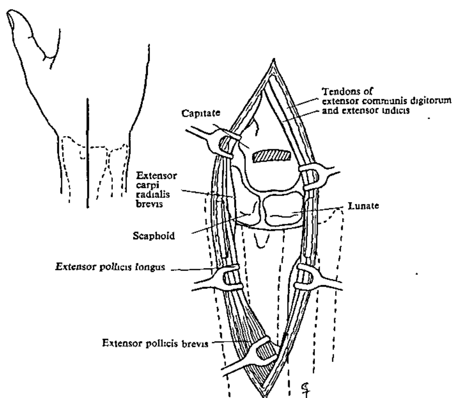


FIG. 182.—Arthrodesis of wrist. Incision and dorsal exposure showing outline of graft area and site of insertion into os capitatum.

may be adopted when ankylosis is of only fibrous type. Particular regions in which this is common are at the knee, the wrist and the tarsal joints. Similar incisions are made as described above, but the exposures required are less wide.

(*d*) *Arthroplasty*

An arthroplasty is, strictly, any open operation to restore movement to a stiff joint; the term is usually restricted to those procedures in which both articular surfaces of a joint are reshaped or a new joint is formed at the site of bony ankylosis with the interposition of some material, either foreign or autogenous, designed to prevent ankylosis. The operation is most suitable for single joints with bony ankylosis, the result of past infection. For those cases in which one would most desire it, namely, generalized ankylosing

arthritis, the operation is generally unsuitable because of the liability to re-ankylosis.

A rarely achieved "ideal"

Arthroplasty is an "ideal" operation in which the ideal is rarely achieved. Because of the large number of very stiff or ankylosed joints in which the procedure should be indicated, its present usefulness can be measured by the relative rarity with which the operation is performed. In the lower extremity when there are single irrecoverably stiff joints, it is difficult to obtain results giving more satisfaction to the patient than ankylosis in the optimal position. In the upper extremity, where mobility is of more importance than stability, arthroplasty would seem to have wider application. Here again it is rarely performed except possibly for the elbow. In spite of all that has been said, arthroplasty is an ideal of which recent technical advances have brought us in closer sight. Operations in the past may have been vitiated by infection and shock. These factors are now more readily controlled. One great difficulty has been the provision of suitable materials for interposition between new "joint" surfaces. Smith-Petersen "cups" of vitallium and other inert metals, for the hip, provide a method, but it must be admitted that the published results have not yet shown any striking improvement in function as compared with that obtained by earlier methods of fascial interposition. Other human requirements remain: physical and psychological stamina in the patient and excellent surgical craftsmanship in the operator. As Higgs has stated: "There is a huge field of research before us, as no one can maintain that a fixed joint is better than a movable one". It is only fair to add that Smith-Petersen himself, who has carried out over 500 hip arthroplasties, has developed a new and most precise technique, associated with a painstaking programme of after-treatment, which offers great encouragement.

Control of infection and shock

Personal factors

Special indications

The special indications for arthroplasty at present are in cases of bilateral ankylosis, particularly of the hip. Cases in which there are active inflammatory changes are unsuitable, as, of course, are cases of healed tuberculosis. Hitherto, joints showing sound bony ankylosis have been considered more favourable than, for example, the pseudo-ankylosis of osteoarthritis.

Technique

Hip (Fig. 172.)—The antero-lateral incision (Smith-Petersen) is used, and is extended downwards over the middle of the thigh to expose the fascia femoris. In the posterior flap are found the gluteus medius, the tensor fasciae femoris and the gluteus minimus muscles (detached subperiosteally from the ala of the ilium) and the greater trochanter, which is sectioned at its base. Anteriorly lie the sartorius origin and deep to it the rectus femoris, the reflected tendon of which arches posteriorly across the lateral aspect of the acetabulum and capsule. Medial to the direct head of the rectus will be seen the iliacus muscle. The anterior and posterior flaps are fully separated throughout the whole length of the incision—careful haemostasis being ensured, particularly of the transverse anastomosing branches of the circumflex vessels. The reflected tendon of the rectus is divided, and as much as possible of the joint capsule is separated cleanly from covering fat and from the muscles in contact with it. The capsule is then incised, as far as possible, in a circular manner, at its distal attachment to the femoral neck and vertically in the line of the wound centre. It is stripped upwards until the old hip-joint line is exposed. A large gouge is then driven into this joint line from the front, side and back, the direction being more in an upward direction than inwards. With the gouge as a lever the head then can

easily be dislocated, if an assistant adducts and externally rotates the femoral shaft. Thereafter the rest of the capsule can be divided on the inner side from the femoral neck. The acetabulum and femoral head are then reshaped, the latter being considerably reduced in transverse diameter. The remains of the capsule are invaginated into the acetabulum, completely covering the exposed raw surface, and the femoral head is covered by a flap of fascia lata removed from the lower part of the incision. This flap is applied with the smooth inner surface placed outside, so that after reduction of the femoral head it will be in contact with the invaginated capsule. Gauze sponges applied for subperiosteal haemostasis are removed, and the wound is closed after the greater trochanter has been reattached.

In Smith-Petersen's later procedure the following details should be mentioned: detachment of the whole origin of the rectus femoris muscle and retraction of the ilio-psoas from the anterior pelvic surface; removal of a wide segment, about an inch deep, from the front of the acetabulum. Special offset gouges aid in the separation of the femoral head and the acetabulum, both of which are shaped with reamers. The acetabulum is excavated as far as the inner pelvic cortex. Osteophytes are excised extensively before the metal cup is inserted. Particular attention is paid to haemostasis and to gentleness of handling.

er-
tment

A plasma drip, which will have been given throughout the operation, will be continued as indicated. Immobilization in a plaster-of-Paris spica is used. Early attempts to restore movement are contra-indicated. Biological equilibrium must be achieved in the extensive area exposed. Movements should not be commenced before two weeks. For this, traction upon a counter-balanced Thomas's splint is necessary. The patient can be up with crutches in six weeks, but weight-bearing is not allowed for three months.

(*e*) *Other reconstruction of joints*

Besides what are by convention called "arthroplasty" operations, there are several other procedures which strictly belong to this group. Amongst these are: Whitman's operation; Girdlestone's and Bankart's excision of the hip-joint; the Keller and Mayo operations for hallux rigidus or hallux valgus; excision of the head of the radius and of the lower end of the ulna.

(i) *Whitman's operation.*—This reconstruction, which has special indication in ununited fracture of the neck of the femur, involves the removal of the femoral head, the detachment of the great trochanter, and the replacement of this lower down on the outer side of the shaft of the femur, the neck of the femur being replaced in the acetabulum.

(ii) *Bankart's operation.*—Bankart's operation was designed for the treatment of tuberculous disease, but by its author has been used in cases of osteoarthritis. The operation is a formidable one involving excision of the acetabulum as well as of the head of the femur; so far there are no published results available.

(iii) *Girdlestone's operation.*—This operation for hip-joint reconstruction similarly involves the formation of a pseudo-arthrosis. The Smith-Petersen approach is made. The capsule and synovial membrane is excised from the front and sides of the joint. In order to make the process of dislocation of the femoral head easier, and so minimize shock, the anterior and upper rim of the acetabulum is gouged off. After dislocation, the neck of the femur is cleanly

divided at its distal end by a saw. Any bony irregularities of the neck and of the acetabulum are removed and the wound is closed. The after-treatment is carried out upon a Thomas's bed knee splint with a Pearson knee hinge, and with sufficient traction to maintain normal length of limb. Active flexion and extension movements of the hip are started after two weeks. At the end of six weeks, Russell traction is substituted for the splint, so permitting freer movement and more easily applied local physical therapy. In a further week, the patient is up with non-weight-bearing exercises, and after another week a weight-relieving caliper is applied and is used with the help of crutches, which are soon replaced by walking-sticks. Girdlestone's figures for osteoarthritis are : twenty-five patients operated upon between 1924 and 1940, of whom in twenty-two end-results have been ascertained. There was no operative mortality; fourteen results are classified as excellent, five as good and three as poor.

After-treatment

Bristow, reporting in 1934 on 98 cases of non-tuberculous arthritis *treated by operation, included in the review forty-two arthroplasty operations* and fifty-six arthrodeses. The group of arthroplasties included an unspecified number of Whitman reconstructions. The two methods are grouped together as being the operation of choice for the old ununited fracture of the neck of the femur and chronic arthritis when both hips or the hip and knee on the same side are stiff. The proportion of arthroplasty to arthrodesis would now, by most writers, be considered excessive, in view of the proved success of the operation of nail arthrodesis for single arthritic hips.

(iv) *Excision of head of radius.*—Relatively minor operations can be of great importance in providing relief from arthritis of the superior or inferior radio-ulnar joints, when there is pain and limitation of pronation and supination.

Excision of the radial head is carried out through a lateral incision along the line of the anterior fibres of the anconeus muscle, the radial collateral ligament being stripped posteriorly from the lateral epicondyle, and the anterior capsule divided from the humerus. Care is taken to avoid the posterior interosseous nerve. The neck of the radius is divided without subperiosteal stripping, and is covered over by remnants of the orbicular ligament. Early movements are started.

(v) *Excision of lower end of ulna.*—Through a medial incision the soft tissues are separated from the ulna, again without subperiosteal stripping; the collateral ligament is divided from the styloid process of the ulna, which is then sectioned an inch or so above the joint. The remaining attachments to the radius are divided and the proximal end of the ulna is covered over with soft tissue.

(vi) *Patellectomy.*—This operation may be associated with synovectomy in those cases in which the patello-femoral articular surfaces are grossly destroyed. It is recommended, however, that the excision of the patella should be done at a separate operation; for the after-treatment of synovectomy involves a more active early programme than is advisable for the patellectomy.

The operation has a certain indication in osteoarthritis of the knee-joint, when the changes more particularly affect the patello-femoral surfaces, and when the symptom of pain is clearly related to the movement of the patella over the femur.

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ARTHROGRAPHY

See JOINTS

ARTIFICIAL LIMBS

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1. PREPARATION OF PATIENT

(1) General

39.] This is designed to improve morale and provide encouragement; in many cases the manner in which it is carried out determines the ultimate success or failure of the patient as a limb user. It is work in which all those who associate with the patient from the time of amputation onwards can participate. To be enabled to do so to the best advantage, however, some knowledge is necessary regarding the conditions and problems which have to be faced by those who lose a limb. *Morale*

All who suffer amputation experience a degree of mental shock which results, in many cases, in despondency and a feeling that there is no future but a life of crippledom and dependency upon others. *Mental shock*

Very often this despondency becomes associated with anxieties, particularly those of a financial nature. Patients feel that their disablement will prevent them from contributing towards the upkeep of a home; that the cost of limb supplies, repairs and adjustments in future will fall very hard on them. Anxieties such as these not only retard convalescence but also cloud the *Anxiety*

future. When there are any financial schemes in force through which an individual case may benefit, it is very necessary that the patient should be informed of these at the earliest possible moment.

Between amputation and the supply of a limb there must always be, unfortunately, a period during which these distressing ideas may develop and become intensified in the mind, unless they be neutralized as far as is possible by those in association with the patient.

(2) Rehabilitation

Mental treatment

During this waiting period, therefore, we should direct our attention towards providing not only physical treatment, but also mental treatment which gives confidence and hope for the future.

The advantage of assembling and treating amputated persons in one institution cannot be over-emphasized, because by this method patients observe and receive encouragement from others who are in a more advanced stage of limb fitting than they are themselves.

Films

The showing of films taken of those who have been fitted with limbs and are rehabilitated has proved to be of the greatest benefit, but when the films portray patients having amputations at various levels, the patients should be advised to concentrate upon the activities, gait and appearance of those who have suffered the same amputation as themselves.

Future ability

Care is needed in advising a patient regarding his future potentialities. Whereas harm may be done in under-estimating the patient's future ability, over-optimism should be avoided. When giving verbal encouragement, which is very often needed, to an individual patient, it must be realized that the success of each individual is dependent upon a number of factors such as:

(a) the level at which the amputation has been performed;
(b) the presence of disabilities additional to the amputation;
(c) the general physique and age;
(d) personality and the degree of ambition capable of being instilled into the patient.

These factors should be investigated first in order to avoid giving false encouragement which can result only in the patient losing faith in his adviser, in his limb-maker and, ultimately, in himself.

(*a*) *Loss of arm*

Greatest disablement

The greatest disablement from the functional point of view is the loss of arms and, this being so, we can expect to find, as we do, that the mental shock of the loss of the limb is greater amongst those who lose arms than those who lose legs; but under favourable conditions, and after proper training, an amputee above the elbow can be restored to 50 per cent efficiency, and a forearm case can be restored to 75 per cent efficiency.

Former trades

If the patient concerned, before the loss of the arm, was already skilled in some trade, his chance of success in returning to that trade, or some similar trade, is enhanced. Generally speaking, work which entails the use of the coarser movements is more to be desired for these cases, though there are exceptions. It is emphasized that training in the use of the artificial arm is essential; without it success cannot be expected.

Appliances

For working purposes appliances are made for use with artificial arms, and

these, after removal of the hand from the artificial arm, are snapped into position. If the level of amputation permits, the forearm of the artificial arm is bisected in order that the working appliances may be brought as near as possible to the motive power. A very large number of appliances are available which enable patients to take up many trades and occupations.

Possible occupations

In accordance, therefore, with the level of amputation, the personality and the ambition of the patient, those who have lost arms can engage in such occupations as carpentry, metal work and many branches of engineering, welding, the electrical trades, and the building trades, including bricklaying (for forearm amputation)—to quote but a few—and in those occupations involving the coarser movements, such as boiler stoking and various agricultural pursuits.

The foregoing remarks are concerned with the patient's ability to earn his living while wearing an artificial limb, but consideration must also be given to the patient's ability to enjoy his leisure hours.

Possible recreations

A patient whose arm has been amputated is enabled with the use of an artificial limb to engage in a number of sports such as cricket and golf, suitable appliances being designed for this purpose; appliances have been designed to enable those who wish to do so to shoot, to write, and to play indoor games such as billiards and table tennis (for forearm amputations); and appliances are available to enable patients with double forearm amputations to play cards. Fly-fishing can be, and has been, successfully undertaken by those who have forearm amputations.

(*b*) *Loss of leg*

Possible occupations

Patients having good thigh stumps are known to have been engaged for many years in occupations such as the following: crane driving, boiler making, boiler stoking, all branches of the engineering trade and electrical industries, the building trade, carpentry, all the retail trades—in fact any occupation which does not involve too much walking or stair climbing. It is not abnormal for patients having this amputation to stand all day at the bench. Individuals with very short thigh amputations, and those who have been disarticulated at the hip, are not normally expected to engage in work entailing much walking about, and sedentary work is perhaps more usual; but very many such patients are standing at the bench all day, and riding a pedal cycle to work every day. In this particular branch of the work, as in all other branches of rehabilitation, much depends upon the personality and the physique of the individual. Patients with amputations below the knee are, as a rule, able to return to their previous occupations and, from the point of view of employment, cannot be regarded as very much disabled; in fact, many do not regard themselves as being disabled.

The ability to engage in remunerative employment together with the ability to enjoy their leisure hours, enables patients to return to a reasonably normal life despite the disability.

Spirit of independence

A further matter requires some emphasis. We must recognize and respect the spirit of independence which appears to be firmly rooted in all or nearly all amputees. Their great desire is to appear normal, to walk normally and thus to elicit no interest in their disability from passers-by, and whilst they accept sympathy out of politeness, they certainly do not desire it. They desire to engage in work which is well up to and not beneath their capacity.

2. PREPARATION OF STUMP FOR ARTIFICIAL LIMB

From the earliest possible moment after amputation, treatment should be directed towards the elimination of any flexion deformities which may have developed. To avoid hip flexion, for instance, no pillow should be used beneath a thigh stump or knee-joint.

(1) Exercises for arm and leg

When the stitches have been removed, early and gentle active exercises should be commenced by the patient.

(a) Shoulder movements for the above-elbow stump.

(b) Shoulder and elbow movements for the forearm stump.

(c) Adductor exercises for the thigh stump whilst the patient is lying in bed, and extensor exercises which can be practised by his lying prone on the bed with the hands clasped behind the neck, the head and shoulders being raised from the pillow.

(d) For below-knee amputations, quadriceps exercises.

Arm: special treatment

At this stage arm amputation cases require a special form of treatment designed not only with a view to mobilizing joints and re-educating muscles, but also for purposes of mental rehabilitation and the development of a stump sense.

Unless a patient, whilst waiting for limb fitting to commence, be encouraged by various means to make use of the stump, he becomes not only "one-hand minded" but proud of his ability with the remaining hand—a condition which the ultimate supply of an artificial arm does not always correct.

(2) Appliances and aids

Writing

If, for instance, a patient is right-handed and loses the right arm above or below the elbow, he should be enabled to write with the stump at once. This can be accomplished by various means such as bandaging a pencil or pen to the stump, or fastening it thereto by surgical strapping (*see* Fig. 183), by a plaster mould of the stump into the end of which is fitted a pen or pencil, or (as is usual at Roehampton Limb Centre) a leather gauntlet fastened by two straps and buckles, and having two slits in the leather through which passes a pen or pencil. This is adjustable and can quickly be strapped to any stump, whether above or below the elbow, and used for writing straight away.

Blackboard writing

Another leather gauntlet is used on to which is riveted a metal tube designed to hold a piece of chalk. This is very useful for blackboard writing for both above-elbow and below-elbow cases, but it is particularly useful for above-elbow cases, in which the patients have overcome limited shoulder movement through its use. (*See* Fig. 184.)

Patients are encouraged to write on the blackboard with this at a certain level marked on the board by a line. The level of the line is raised day by day, and this method of enabling a patient to do something he naturally wants to do, combined with mobilization of the shoulder-joint, has been found to be of the greatest value. All these temporary "writing gadgets" can be made easily in any hospital which has a plaster shop or leather shop.

Feeding

Patients should be encouraged and enabled to feed themselves, using their stumps, on to which a fork or spoon has been attached by a bandage or other means. These methods of rendering a patient independent are not only of the

greatest value for single-arm amputation cases, because they encourage the use of the stump and a return to normal action, but they are essential for double-arm amputation cases to enable patients, at the earliest moment, to become as independent of others as possible whilst they are waiting for artificial limbs to be supplied.

Loss of both arms

For these double-arm amputations a piece of wire with a loop at the end can be bent around the stump, and into the loop a cigarette can be fitted;



FIG. 183.—Patient writing with pencil attached to stump by surgical strapping.



FIG. 184.—Patient writing on a blackboard using an adjustable leather gauntlet.

this enables a patient to smoke in greater comfort. A piece of indiarubber attached to the stump end enables them to turn the pages of a book unaided. All those who have lost arms should not only be enabled, but also encouraged to act on the lines suggested above at the earliest possible moment after amputation. The benefit from the morale point of view is pronounced.

3. STUMP BANDAGING

Purpose

The purpose of bandaging the stump in the manner about to be described is to prepare and shape it ready for the fitting of a permanent limb by the removal of oedema. Although in past years a plaster pylon has been used alone for this purpose, it is found that the bandaging system has the advantage that it can be commenced earlier than it is advisable to supply a plaster pylon and, therefore, time is saved in preparing the stump; a plaster pylon, at a later date, will render the patient ambulatory pending the fitting and supply of the permanent limb.

Both methods are therefore advocated, but the bandaging method should always be used whether a pylon be issued or not. This principle of bandaging can be applied even before the stump is healed, provided that the tension of the first three turns or slings of the bandage over the stump end is suitably modified. When the stump is soundly healed, the tension over the extremity is gradually increased up to the maximal amount tolerable to the patient.

Best type of bandage

The best type of bandage has been found to be the crêpe bandage, which appears to have just the right amount of residual elasticity.

(1) Bandages

(a) Sizes

(i) For arm amputation stumps: one bandage 3 inches wide.

(ii) For amputations below the knee if the stump does not exceed 6 inches: one bandage 4 inches wide.

If the stump is particularly bulky, or more than 6 inches long: two bandages 4 inches wide, sewn together end to end, may be necessary.

(iii) For thigh stumps : two bandages 6 inches wide (not less), sewn together end to end, should be used.

(b) Preparation

Reapplication of bandages

Before application, new bandages should be unrolled (and sewn together end to end as suggested above where necessary) and re-rolled in such a manner that the majority of the stretch is removed from the bandage in the rolling process. Even so the bandage still has a considerable amount of residual elasticity; it will stretch and the stump will shrink. Therefore, it is advocated that the bandages should be reapplied not less than three times a day, and should be worn all night if the desired result—rapid and progressive shrinkage of the stump—is to be achieved.

(2) Shrinkage of stump

When properly applied, the result should be that the greatest shrinkage would take place at the stump's extremity, while the least amount of shrinkage takes place at the upper extremity.

Measurement

It is advocated that circumferential measurements of the stump should be taken prior to commencing the bandaging. If it is a thigh stump, one measurement should be taken one inch below the perineum, one at the centre of the stump and one two inches above the extremity. These measurements should be repeated every two or three days, and recorded. It thus can be ascertained that shrinkage is taking place in the correct manner, and that the bandaging is being properly carried out.

At home

This system will be commenced, of course, whilst the patient is being treated in the hospital, but should be continued on discharge. Patients are instructed how to perform the technique, with the aid of a member of the family. It is advisable that such instructions should be given, because the bandage should be applied and worn at night for about four months after a first limb has been issued.

(3) Method of bandaging

(a) Thigh stump

When first presented, a primary thigh amputation has what might be termed a bulbous or square-ended extremity and it is necessary to reduce and conify this stump (*see* Fig. 185).

Application of bandage

Two 6-inch-wide crêpe bandages will have been rolled as indicated above; with the patient recumbent, the free end of the bandage is placed upon the front of the stump at the level of the inguinal ligament, where it is held in position by the patient's two thumbs (*see* Fig. 186). The operator now draws



FIG. 185.—A primary thigh amputation as it appears before bandaging is commenced



FIG. 186.—The bandage held in position by the patient's two thumbs.



FIG. 187.—With the stump flexed to 45°, the bandage is held by the patient's thumbs and forefingers



FIG 188.—Three slings of the bandage embrace the stump's extremity.



FIG. 189.—The operator now twists the bandage.



FIG. 190.—Taking a turn round the upper part of the stump.



FIG. 191.—Bringing the bandage from the extremity high up to the level of the buttock.



FIG. 192.—The cross-over of the bandage will be external.



FIG. 193.—The bandage will be brought down on to the stump extremity.



FIG. 194.—Bandages carried as high up to the perineum as possible.

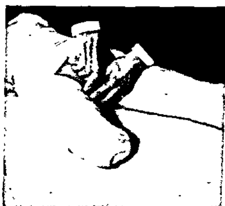


FIG. 195.—Bandages carried as high up to the perineum as possible.

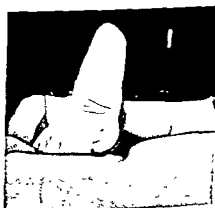


FIG. 196.—Full movements are permitted when the bandage has been correctly applied.

the bandage down centrally in tension over the stump's extremity whilst, at the same time, the patient flexes his thigh to about 45°. The operator then carries the bandage, still in tension, up to the level of the gluteal fold, where it is held in position by the patient's two forefingers (*see* Fig. 187). The operator then brings the bandage down slightly obliquely and externally over the stump's extremity in tension, and up to the highest point in front, where it is again held by the patient's thumbs, thence down slightly obliquely and internally over the extremity, and up to the gluteal fold, where it is held again by the patient's forefingers.

Slings

We now have three slings over the stump's extremity embracing the centre and lateral angles, which are now compressed by the bandage (*see* Fig. 188). The operator now twists the bandage (*see* Fig. 189) and takes a turn round the upper part of the stump, with sufficient tension only to secure the upper



Fig. 197.—For amputations below the knee the method of applying the three initial slings is the same as that for thigh stumps.



Fig. 198.—The bandage is carried above the femoral condyles.

extremities of the three slings (*see* Fig. 190), after which the patient can remove his hands.

The operator now carries the bandage down to the stump's extremity as he covers it on each occasion, using tension over that point. Then, bringing the bandage from the extremity high up on the outer side to the level of the buttock (*see* Fig. 191), he passes it round the pelvis and back on the stump, again making a spica turn. It is most important that the cross-over of the bandage shall be external and not anterior (*see* Fig. 192). If the cross-over be anterior through the bandage not having been carried high enough up to buttock level before making the pelvic turn, a flexion deformity will result. After making the two pelvic turns, the bandage will be brought down on to the stump extremity (*see* Fig. 193), using tension again, and up to the perineum as high as possible (*see* Figs. 194, 195).

External cross-over

It is most important that the bandage should be carried high up into the perineum; the tension employed at that point will, of course, be considerably less than that employed over the extremity. If the bandage be not carried to the perineal level, a roll of flesh will appear between the perineum and the top of

Bandage high up into perineum



Fig. 199.—The knee-joint is left exposed to permit of quadriceps exercises being carried out.

the bandage, over which it will hang, and cause later troubles when limb fitting commences. Full movements of flexion, extension, abduction and adduction are permitted when the bandage has been correctly applied (*see* Fig. 196).

(*b*) *Amputation below knee*

Application and slings

For an amputation below the knee one 4-inch bandage (or two may be necessary) is used, having been stretched prior to rolling. The method of application and the applying of the three initial slings are exactly the same as described above under thigh stumps (*see* Fig. 197). After the three slings have been put in place and the extremity has been bandaged in tension, the bandage is carried up above the femoral condyles as indicated in Fig. 198, after which it is carried down on to the stump again where it is finished off (*see* Fig. 199). The knee-joint is left exposed, and the patient can carry on quadriceps exercises whilst wearing a bandage.

(*c*) *Arm amputation*

Below elbow For below-elbow amputations use a 3-inch-wide crêpe bandage; the same principle is adopted as described under (b) above.

Above elbow For amputations above the elbow, a 3-inch bandage is used.

4. STUMP EXERCISES (LEG)

These can be carried out in two stages, as follows:

(1) In bed

These exercises are already referred to above in the section on Preparation of Stump for Artificial Limb.

(2) When able to get about on crutches

Physiotherapy As soon as the thigh stump is healed and the patient is allowed up on crutches, he will go to the physiotherapy department where apparatus is fitted, and used, as follows.

Apparatus A piece of timber 12 feet by 6 inches by 2 inches is fixed horizontally to the wall, 4 feet above ground level. To this is fitted a series of pulley wheels, 3 feet apart. A piece of blind-cord 9 feet long passes over each pulley; to one end is attached a sand-bag weighing 5 pounds to commence with, the weight later being increased to 15 to 21 pounds. To the other end is attached a canvas stump sling shaped as shown in the diagram. A handrail is situated at such a distance from the wall that when the sling is

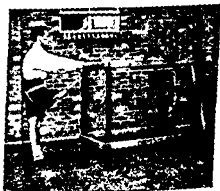


Fig. 200.—Hip extensor exercises.

attached to the stump and the patient is resting his hands upon the rail, the sand-bag is just clear of the floor. With the patient standing sideways to the wall, extensor exercises are commenced, adductor exercises being performed when he stands facing the wall. (*See* Figs. 200, 201.) Two exercise periods of twenty minutes each daily, continued for at least a week, will redevelop the stump muscles sufficiently for limb wearing.

Exercises



Fig. 201.—Adductor exercises.

Use of stump

The need for re-education of the adductor and extensor muscles is determined by the use to which the stump is put when the patient is walking on an artificial limb supplied for a thigh amputation.

Stance

When he is standing at attention on an artificial limb the adductor muscles must be contracted to prevent the limb from breaking away at the hip. When he takes a pace with the artificial limb the latter must be carried directly forward in the adducted position, otherwise a circumducted gait will result. When the heel of the artificial limb touches the ground at each pace the artificial knee is slightly flexed to produce extension which is necessary in order to prevent the limb giving way beneath the patient; the extensor muscles of the hip come into action and produce extension of the shin on the knee. The use of the extensors is again essential when a patient is ascending or descending stairs.

Gait

This apparatus is adaptable for the development of the quadriceps in below-knee cases.

Competitive spirit

The introduction of the competitive spirit in these exercises is of great value, and patients are found to take a great interest in the results.

Exercises at home

Exercises can be done by out-patients in their own homes. For thigh stumps, a home-made sling, a blind-cord and a flat-iron will serve, the cord passing over the back of a chair upon the seat of which someone is sitting. Concurrently, exercises should be given for strengthening of the erector spinae and abdominal muscles before the limb is supplied.

Arm stump

For arm stumps, joint movements to elbow and shoulders are practised, and patients are encouraged to use their stumps in playing with a large soft ball, always assuming that the stump sensitivity has become normal.

5. TRAINING IN USE OF ARTIFICIAL LIMBS

(1) Leg

The stump exercises which have already been given will have done much to prepare the patient to use a limb correctly, and will have been sufficient to enable him to walk on the limb under the supervision of the limb fitter



Fig. 199.—The knee-joint is left exposed to permit of quadriceps exercises being carried out.

the bandage, over which it will hang, and cause later troubles when limb fitting commences. Full movements of flexion, extension, abduction and adduction are permitted when the bandage has been correctly applied (*see* Fig. 196).

(*b*) *Amputation below knee*

Application and slings

For an amputation below the knee one 4-inch bandage (or two may be necessary) is used, having been stretched prior to rolling. The method of application and the applying of the three initial slings are exactly the same as described above under thigh stumps (*see* Fig. 197). After the three slings have been put in place and the extremity has been bandaged in tension, the bandage is carried up above the femoral condyles as indicated in Fig. 198, after which it is carried down on to the stump again where it is finished off (*see* Fig. 199). The knee-joint is left exposed, and the patient can carry on quadriceps exercises whilst wearing a bandage.

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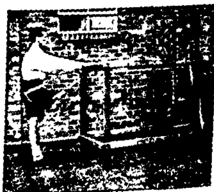


Fig. 200.—Hip extensor exercises.

that both feet shall be kept between these lines to secure adduction of the artificial leg and prevent any tendency to circumduction. The mark should be made at each stage with both legs. A short, slow pace only should be taken and an equal time period spent upon each pace; the head should be erect, the shoulders back, and the eyes should be fixed at a point at the same level on the opposite wall.

Music

At this stage it is helpful if the exercises be carried out to music.

Exercise 5.—(i) Stand erect with feet apart and arms fully extended laterally holding the walking-sticks; commence to swing the sticks with a backward small arm circle. (ii) Exercise as above but with a full swing of the arms and sticks, making a complete circle in front of the body.

Exercise 6.—Stand erect at attention holding the sticks at their centres; swing the arms with a natural arm swing as if marching, preferably in time to music.

Exercise 7.—Continue as from 4 above, walking along the painted lines, but without making a mark or pausing—in effect, a slow march. It is desirable to use music of strict tempo from a gramophone or wireless set. The benefit of using music is immediately apparent, in that it causes a martial bearing and a natural swing of the arms, with equal time periods spent upon the artificial limb at each pace.

Exercise 8.—Ascending or descending stairs using two sticks. In ascending, commence with the good leg in advance; in descending, commence with the artificial leg in advance. If the amputation is above the knee, the patient should be advised to ensure full extension of his stump at each step of the artificial leg.

Exercise 9.—After completing exercises as in 8 above, the patient should now walk with sticks between two parallel lines 4½ inches apart.

Alternative method

Exercise 10.—Repeat Exercise 4 between the 9-inch lines, only holding both sticks in their centres, swinging the arms as indicated in 6 above, first using a pause at each step and later in time to music. An alternative method of enabling patients—particularly double amputation cases or very nervous single thigh amputees—to learn to balance is the aerial parallel-bar system. For such cases this method can be used prior to commencing the series of exercises with sticks referred to under 1 to 10 above. (*See* Fig. 202.) The aerial parallel-bars are similar to the ordinary parallel-bars used in a gymnasium and found in all limb-makers' fitting-rooms, except that the bars are fitted to four uprights 7 feet high and can be adjusted to any height from the ground between 5 feet and 7 feet. The patient, standing between the bars, holds on to each with his hands at a convenient height above his head. As he walks he slides his hands along the bars. In this manner any tendency to lordosis resulting from leaning forward, such as may arise with using ordinary walking rails, is obviated. By this time

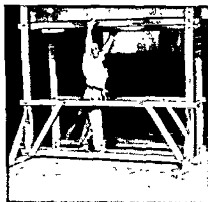


FIG. 202.—The aerial parallel-bar; note the erect stance of this double-amputation patient.

whilst the limb is in the constructional stage. Ultimate perfection of gait, however, depends upon further and more general muscle development and practice, which can best be given, when the limb is finished, in a walking training school where numbers can be collected together under an instructor.

Balance

The circumducted gait is now largely cured by proper muscle re-education before a limb is supplied, and it is necessary, therefore, to concentrate in the walking training schools upon teaching a patient to balance on the artificial leg. Until he can do so, the limp will not be eradicated, partly because the tissues over the ischial tuberosity have not become hardened, and because the patient continues to be nervous of keeping his weight upon them for sufficient periods of time. In learning to balance, therefore, the patient becomes accustomed to weight-bearing, and also develops the abductor and adductor muscles, and the extensors of the hip.

Weight-bearing

Supervision and graduation of exercises

It is necessary that all the exercises about to be described for those just supplied with their first artificial leg should be carried out under strict supervision, and be carefully graduated for each individual from the commencement. There is a natural tendency for many of these patients to desire to run before they can walk, and attempt to do more than they should at any one time, with resultant tiredness and overstrain of the stump muscles. Therefore the exercises must be carried on for a few minutes only the first day, with frequent rest intervals; exercises will be lengthened and the rest period shortened as the patient progresses from day to day.

(*a*) *Exercises in the walking training school*

These are undertaken with the object of teaching balance on and confidence in the artificial limb.

Walking sticks

Each patient should use two walking-sticks, not one, whether his be an above-knee or below-knee amputation, and it is important, if lordosis is to be prevented, that the sticks should be of the correct length, and not too short.

Nervous patients

Exercise 1.—Stand erect at attention supported by sticks; flex the thigh and knee of the good leg and return to ground; flex amputation stump and artificial knee, and return to ground. (For nervous patients this exercise can first be carried out by the patient holding on to an object at shoulder height, or holding the hand of, or placing his hands upon the shoulders of, the instructor, who stands facing him.)

Exercise 2.—Commence with the stump exercises as above, but, at each flexure of the natural leg and the amputated leg, lift both sticks momentarily from the ground. (As the exercise continues the instructor will gradually increase the period of balance during which the sticks are lifted from the ground.)

Exercise 3.—Stand erect as in 1 and 2 above, flex the hip and knee of the good leg sharply, and bring heel to the ground with the knee extended, as if kicking a ball or making a "mark" as when playing Rugby football. The mark should be made not more than 3 inches in front of the level of the toe of the other foot. Repeat this exercise with the artificial foot. (As the heel of the artificial foot touches the ground, the patient forces his stump to the back of the socket and extends the knee.)

Exercise 4.—When Exercise 3 has been practised, walking now commences between two parallel lines painted upon the floor 9 inches apart. It is intended

have received the necessary encouragement already referred to—approach the subject with any great enthusiasm; but for the great majority the whole position is entirely altered through attending an arm training school in which the instructor is himself wearing an artificial arm.

Possible occupations

Many patients who had resigned themselves to the idea of working as commissionaires, or in a clerical capacity, have at the end of their arm training entered for and become trained in technical work of various types, and though the arm training school is not in any sense of the word a vocational centre, numbers of those who have already passed through it have as a result become trained for and secured employment as craftsmen in various trades. (*See* Figs. 203, 204.)

Carpentry

It has been found that the type of work which is most suitable for the purposes of training people in the use of artificial arms is carpentry, because so many different types of tools must be used and the movements with these tools are many and varied.



Fig. 205.—Two patients with above-, and one patient with below-elbow amputation, digging.

Agriculture

In addition, patients are enabled to engage, under supervision, in various forms of agricultural work and in the use of agricultural equipment, the coarser movements which are involved in this form of work being particularly suitable for above-elbow amputation cases. (*See* Fig. 205.)

Most suitable appliance

Each patient, whether engaged in carpentry or the use of agricultural equipment, is enabled to discover for himself which particular appliance is most suitable to him for his own purpose, the arm training school holding a large stock of appliances for experimental purposes. When it has been determined which types of appliance suit each patient best for the type of work he is about to do, his appliances are then ordered for him.

Duration of training

Patients should attend the arm training school morning and afternoon every day for a week; for most of them this period will be sufficient.

[References to other titles are given under Artificial Limbs in the Index Volume.]

the patient will be able to walk without sticks and should, therefore, now proceed to Exercise 11.

(*b*) *Games*

Exercise 11: *dart playing*.—The value of this and the following games is threefold, in that they teach balance, develop the erector spinae muscles and, by arousing interest in the sport, cause the patient to forget the artificial limb and disablement to some extent. Patients soon become thrilled when they discover their ability once more to engage in such games.

Exercise 12: *table tennis*.—This, apart from arousing interest and widening activity, teaches the patient to balance in various attitudes, and thus aids muscle development.

Exercise 13: *medicine ball exercise*.—Draw three lines on the floor 1 foot apart; place a penny on the centre line. Two patients face one another, each standing about 4 feet away from the outer of the three lines. Each in turn holds the medicine ball with both hands above his head and endeavours to hit the penny and force it over his opponent's line. This is an excellent exercise for general toning up of the muscles and teaching balance and confidence in the limb.

Exercise 14: *out of doors*.—First, using two sticks, walk over rough and uneven ground up and down slopes; climb on to and off a bus. Later, repeat the exercise carrying one stick, and using it only in an emergency.

Exercise 15: *cycling*.—This may be practised by patients with above-knee and below-knee amputations and by those with double below-knee amputations.



FIG. 203.—*A forearm-amputation patient using a smoothing-plane.*



FIG. 204.—An above-elbow-amputation patient writing with the artificial hand.

Exercise 16.—*Golf practice* with a captive ball, indoors or out of doors, *tennis come-back* and *badminton* should be added to the foregoing exercises.

Range of use

All the above exercises can be carried out by patients with single-leg amputations at all levels, as well as by those with double below-knee amputations and those who have lost one leg above, and one below, the knee. In cases of double thigh amputation, patients will not be called upon to use the pedal cycle.

(2) Arm

Few patients, when supplied with their first artificial arm, have any idea what they will be able to achieve with it, and few—always excepting those who

A partial collapse may be "selective" or "deselective" according to whether it is over the lesion or over healthy lung. (*See* Figs. 206 and 207.)

2. INDICATIONS

Diagnostic

Artificial pneumothorax is occasionally induced to permit thoracoscopic inspection of the pleura.

Therapeutic

Pulmonary tuberculosis is the only disease that should be treated by artificial pneumothorax. It should be regarded as an auxiliary to strict sanatorium

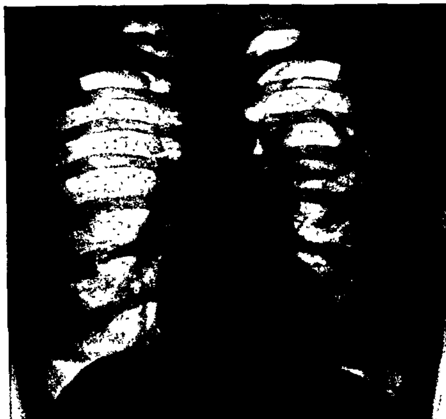


FIG. 206.—Deselective collapse of left lung with large cavity.

routine, and its use apart from sanatorium routine, although sometimes necessary, is not the best practice.

Facilities for adhesiotomy must be available, as this is necessary for the great majority of cases.

Case selection

Opinion differs widely on case selection. Successful results have been obtained in all types of case, from those with bilateral cavitation to the symptomless case, with a minimal lesion discovered by mass radiography, in which it is probably unnecessary.

The common indications are cavitation, persistence of positive sputum, associated laryngeal and early intestinal tuberculosis and, even in minimal cases, the failure to respond to sanatorium routine. Haemoptysis may be an urgent indication.

ARTIFICIAL PNEUMOTHORAX

By PETER W. EDWARDS, M.B.E., M.B., Ch.B.
Medical Superintendent, Cheshire Joint Sanatorium and Wrenbury Hall Tuberculosis Colony, Cheshire

1. DEFINITIONS

40.] Artificial pneumothorax is produced by the introduction of gas into the pleural cavity with the object of permitting relaxation of the lung, for diagnostic or therapeutic purposes. Nowadays it is rare to use any other gas than air. The first introduction of air is termed "induction" and subsequent introductions are "refills". "Adhesions" may be (a) universal between the pleural surfaces and may make an induction impossible, or (b) localized, which may make the resulting collapse partial.

general condition, and the risk of a complicating pleural effusion will be consequently less. If the disease is extensive, bed rest may be augmented by preliminary pneumoperitoneum and perhaps phrenic crush.

Preliminary procedures

The axilla on the affected side should be kept shaved. The skin should be carefully cleansed before each puncture.

5. INSTRUMENTS

Innumerable trocars and cannulae, needles and apparatus are on the market. A short-bevel needle, with side opening and a stilette, is eminently suitable for both induction and refills. More elaborate induction needles are unnecessary.

The apparatus may be portable or fixed. The "dry" types, with bellows for producing the flow of air and an aneroid type of manometer (which must be regularly checked), are easily portable. For clinic use, the types using movable bottles of water, and a water manometer measuring pressures in centimetres, are cheaper, more easily repaired if damaged and much more rapid in action.

"Dry" portable apparatus

6. TECHNIQUE

(1) Induction

(a) Premedication

A sedative, such as a small dose of opium and atropine, should be given half an hour beforehand.

(b) Position of patient

The induction should be performed with the patient in bed, without a pillow, lying with the operation side uppermost. A sand-bag, or preferably a wooden bridge, placed under the chest wall, will arch the chest and thus separate the ribs of the uppermost side. The patient should grip the top of the bed a little forward of his head with the hand of the operation side. He should be told to breathe quietly through the mouth and on no account to hold his breath, that he must be fully relaxed, that he will feel the jag of a blunt needle, and that he should try to give warning of a cough.

Instructions to patient

(c) Local anaesthesia

If a local anaesthetic is used, an intracutaneous weal should be raised and the tissues infiltrated as far as the pleura. Two minutes should be allowed for it to take effect.

Technique

(d) Operative procedure

With aseptic precautions, the stop-cock with needle is attached to the tube which is kept in connexion with the manometer. Needle and tube must be dry.

Select a site in the mid-axilla remote from the main lesion. Apply firm digital pressure on the selected site, and deliberately push the needle through the skin between two fingers, steadied on the ribs, until the pleura is sensed, watching the manometer carefully all the time. When the needle touches the pleura there is usually a flicker of the manometer. A stilette should now be passed gently through the needle and on withdrawal it should still be dry. Gently move the needle forward when the characteristic snap should be felt as it penetrates the pleura.

Technique

If the forward movement is performed slowly and the pleural space is free, the manometer should show a negative pressure. This may be as low as -5 on inspiration and ± 0 on expiration, or higher than -20, -10. If in the

Manometer readings

3. CONTRA-INDICATIONS

Acute pulmonary tuberculosis

Artificial pneumothorax is contra-indicated in all the acute forms of pulmonary tuberculosis and especially in pneumonic phthisis or when cachexia is marked, because of the great risk of complications, especially pleural effusions. It does not benefit miliary tuberculosis.

Gross destruction

When there is gross pulmonary destruction, even though chronic, it is necessary to consider whether a permanent collapse measure (such as thoracoplasty) is not better treatment.

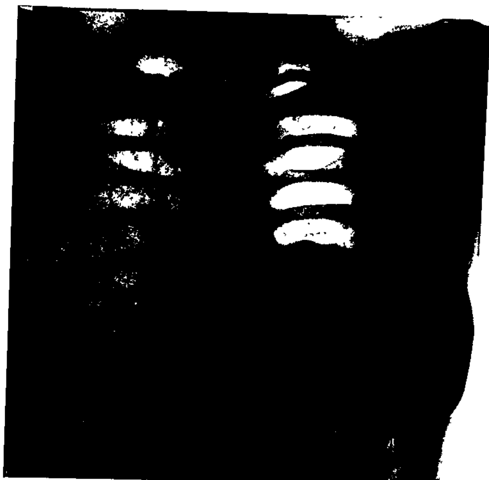


FIG. 207.—Same case as in Fig. 206, after adhesiotomy: satisfactory collapse; cavity closed.

It should not be used where there is marked endobronchial tuberculosis, or associated silicosis, bronchitis, emphysema or bronchiectasis. Well-compensated mitral disease is not a contra-indication, but uncompensated heart disease is. Extrapulmonary tuberculosis, unless itself untreatable, should not preclude its use. Any coexistent fatal disease precludes an attempt.

Age limit

Children tolerate artificial pneumothorax well, but it should rarely be used in patients over 50 years old.

4. PRE-OPERATIVE MANAGEMENT

It is best to have the patient under observation in a sanatorium for a few weeks before induction. There will frequently be a great improvement in the

relaxed and breathing quietly. The pressure varies with posture, and is more positive when he is sitting up than when lying on the uncollapsed side, and higher still when lying on the back.

Example :—lying on uncollapsed side -5 ± 0
sitting up -3 $+1$
lying on back ± 0 $+5$

Positive pressure on both inspiration and expiration with the patient lying on his side is not permissible in the average case.

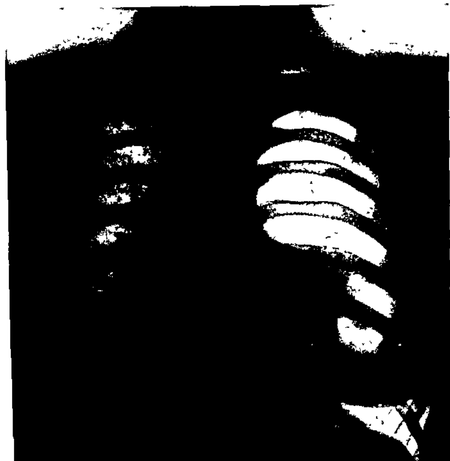


FIG. 208.—Apparent satisfactory collapse of left lung; skiagram taken in full inspiration.

Rarely should one exceed an expiration pressure of ± 0 in this position. If adhesions are present it is bad practice to attempt to improve the collapse by means of positive pressures. The required pressure for each case should be altered, as necessary, when the patient is screened.

Expiration pressure limits

(2) Mobile mediastinum

Control of the mediastinum is essential. Mobility may not be the result of positive pressure nor yet of excessively large refills. Fixation of the mediastinum may be obtained: (a) by the pleural reaction following the instillation of a few cubic centimetres of a solution of Gomenol in oil; but, as the pleuritis

Causes

Gomenol

lower range ask the patient to breathe deeply, when there will be a greater amplitude of swing if the needle is in the pleural space. Valve action of the lung against the needle may sometimes cause a high negative pressure without fluctuations.

If no reading is obtained, again pass the stilette and examine on withdrawal. If there is still no reading, aspirate a little air. Then, if the needle point is in the tissues, a high negative pressure will be registered and will be maintained; if in the lung, a negative pressure may be registered and will slowly fall. If intrapulmonary pressures such as -2, $+2$ are recorded, slowly withdraw the needle while watching the manometer. If this does not produce intrapleural pressure readings, because pleural layers are adherent, remove the needle and try another site. Two attempts are sufficient for one day.

When free negative fluctuations of the manometer are seen, admit air at atmospheric or slight positive pressure. If the patient complains or flinches, air must immediately be stopped. Otherwise admit up to 50 cubic centimetres and then read the manometer. If the manometer still registers a high negative pressure, continue to allow air in to a maximum of 300 cubic centimetres or until a maximal expiration pressure of $+5$ is reached. Afterwards the patient should be encouraged to suppress cough and sleep quietly.

Amount of air

(e) *Air-replacement pneumothorax*

When the presenting symptom is pleural effusion and there is evidence of underlying pulmonary disease, pneumothorax may be established by the replacement of fluid by air. A satisfactory pneumothorax rarely results from air replacement. If there is no underlying disease the effusion should be treated conservatively.

(2) Refills

The first refill is given on the following day under identical conditions. After one day's interval the second refill is given without premedication, and this and subsequent refills need not be given in bed.

7. MANAGEMENT

The aim of artificial pneumothorax treatment is to attain and maintain relaxation of the diseased area of the lung.

(1) X-ray screening and control of collapse

Criteria

Fixed expiration pressure

Difficulties in control

After the second refill the patient should be screened, and the maximal expiration pressure to be aimed at when giving refills should be provisionally fixed. This will depend upon the degree of collapse obtained, the presence of gross adhesions or pleural effusion, the movement of the diaphragm, the position and behaviour of the mediastinum and the condition of the contralateral lung. A more uniform collapse is maintained by refilling to a fixed expiration pressure rather than by giving a fixed quantity of air. Screening is desirable once a week, preferably before a refill, when the maximal re-expansion which takes place in the intervals can be observed. During deep respiration a mobile mediastinum will swing to the contralateral side on expiration. Hernia of the upper mediastinum into the contralateral hemithorax may occur at the same time. Both these conditions make control of the pneumothorax more difficult.

During measurement of the intrapleural pressures the patient must be

A return of symptoms between refills, or increased sputum after refills, usually indicates that the intervals are too long.

(5) Satisfactory collapse

The diseased area of lung should be completely relaxed and not subject to the tug of adhesions between the lung and the chest wall. Adhesions are present in fully 95 per cent of cases. They can usually be seen in an x-ray film of the chest, taken in full expiration four or five weeks after induction. This is a suitable time for adhesiotomy.

Adhesiotomy

(6) Thoracoscopy

Thoracoscopy and adhesiotomy are an essential part of artificial pneumothorax treatment, which must be considered an exploratory procedure until thoracoscopy shows that the collapse is effective. X-ray screening and radiography will not prove this, and the operability of adhesions cannot be assessed radiographically.

An artificial pneumothorax which does not allow relaxation of the diseased area, even after subsidiary measures, should not be maintained; for although it may be followed by an early improvement, the high incidence of complications makes the prognosis worse than in similar cases not treated by artificial pneumothorax.

If a tension cavity enlarges after induction of pneumothorax, adhesiotomy should be postponed, because of the danger of cavity rupture. A reduction in the size of such a cavity frequently follows temporary phrenic paralysis reinforced by pneumoperitoneum, and adhesiotomy may then be undertaken with less risk.

Adhesiotomy: indications

(7) Duration of treatment

Each case is a law unto itself. The aim is control of tuberculosis, and it is impossible at the commencement to estimate the time needed for this or the complications, particularly contralateral disease, that may arise. Four years' *effective* collapse is usually enough, but many pneumothoraces will obliterate in a much shorter time.

(8) Abandoning the artificial pneumothorax

Either reduce the pressures and lengthen the interval between refills, or merely cease refills. The latter is simpler and without disadvantages, but during the re-expansion period the patient should be screened and radiographed at monthly intervals.

8. COMPLICATIONS

(1) During operation

(i) Wounding an intercostal vessel usually causes a haematoma of the chest wall, but occasionally a haemothorax may follow. Puncture of the lung may cause damage to a small pulmonary vessel, and may be followed by a small haemoptysis. The patient should be reassured, as it is of no significance. Laceration of the lung may follow a cough when the pneumothorax space is small. The wound may heal in two to three days or may persist as an open broncho-pleural fistula.

Haematoma

Laceration

may be severe with *persistent effusions*, this method is not recommended; (b) by giving refills with the patient lying flat on the back, and encouraging him to lie always on the side of the collapsed lung. This method is free from risk and usually succeeds.



FIG. 209.—Same case as in Fig 208: gross displacement of heart and mediastinum; skiagram taken in full expiration.

(3) Quantity of air

As continuous relaxation is the aim, it is better to give *frequent small refills* than large ones at longer intervals, in which case the lung is subjected, concertina-like, to periods of collapse followed by re-expansion, and gets little rest. Three hundred cubic centimetres is the optimal quantity and 500 cubic centimetres the maximum. *Individual variations in the rate of absorption* of air are great.

Optimal refill

(4) Spacing of refills

At first, absorption of air is rapid, and frequent screening and refills are necessary. The average case requires three refills a week for a fortnight, then two a week for a variable period. When a satisfactory collapse is established with or *without adhesiotomy, weekly refills will probably* be necessary for six months. The interval may be lengthened when the quantity of air required to reach the required pressure is 300 cubic centimetres or less.

If there is a pleuro-pulmonary perforation, closed intercostal drainage is better, and the drainage site should be in the axilla, as a plastic operation may be called for later.

Drainage

(4) Broncho-pleural fistula

If small, this frequently heals and the artificial pneumothorax may be maintained. The valvular type which causes tension pneumothorax is best treated by constant suction through a suitable cannula for a few days. If it heals in less than two days the artificial pneumothorax may be maintained; otherwise the best hope is to obliterate the pneumothorax space as rapidly as possible. Persistent broncho-pleural fistula causes empyema usually due to mixed tuberculous and pyogenic infection.

Treatment

(5) Obliterative pleuritis

Many artificial pneumothoraces obliterate by pleural symphysis in spite of refills. The obliteration will progress slowly even against dangerously high pressures. Alternative collapse measures must be considered.

Pleural symphysis

(6) Unexpandable lung

This condition seems to be common in some countries but it is rare in Great Britain. It may cause bronchiectasis and pleural effusion. Many lungs become atelectatic during artificial pneumothorax treatment, but they usually re-aerate with proper control of refills.

9. BILATERAL ARTIFICIAL PNEUMOTHORAX

Although case selection must be more careful than for unilateral collapse, bilateral pneumothorax has a much wider application than many writers imply. The patient should be under 40 and the cardiovascular reserve should be satisfactory. Pleural effusion or empyema may cause grave respiratory embarrassment, so generally speaking the disease should be less acute in type to lessen the risk. It should be remembered that adhesiotomy will probably be necessary on both sides. The ideal case has disease restricted to one lobe of each lung, and when good selective collapse is obtained on each side, such a patient has little or no respiratory embarrassment.

Indications

The general rules of management apply, but it is inadvisable to exceed 400 cubic centimetres of air at a refill. Many patients are more comfortable when filled lying on the back.

The complications of artificial pneumothorax are naturally more common when both lungs are collapsed. The incidence of broncho-pulmonary fistula is high, and much more grave than in a unilateral pneumothorax.

Increased liability to complications

10. AUXILIARY PROCEDURES

(1) Phrenic nerve crush

This operation, by causing temporary diaphragmatic paralysis, may make an ineffective artificial pneumothorax effective, especially when the upper lobe is adherent to the upper mediastinum, or when a lower-lobe cavity remains open. Reference has already been made to its use prior to adhesiotomy when a tension cavity is enlarging.

Emphysema

(ii) Surgical emphysema will occur if the needle slips out of the pleural cavity during a refill, or as a result of much post-operative cough. It may be painful, but it is of no importance as a rule.

Embolism

(iii) Air embolism results from air entering a pulmonary vein, and when it reaches the cerebral arteries it causes localizing symptoms, such as headache, giddiness, loss of consciousness, various pareses and loss of vision. Bubbles

Retinal air emboli

have been seen in the retinal arteries. In most reported cases air has not been introduced, so it must have been sucked into the punctured vessel from the needle and connecting tube, or from the lung itself. Some fatalities have occurred, but usually the symptoms are transitory even when severe. There is no treatment, but supportive measures are usually applied.

(2) Pleural effusion

(a) Serous

The exact causation is unknown. Small serous effusions are common and of little importance. They are usually symptomless and noted first at screening, or suspected by a reduction in the size of refill needed, but there may be some chest pain requiring simple analgesics.

Large effusions may have a boisterous onset, with fever, pain and dyspnoea. The patient should be kept strictly at rest and a specimen of the fluid investi-

Treatment

gated. Unless there is much dyspnoea, it is unwise to aspirate a serous effusion until the temperature settles. It is best to aim at keeping the pleura dry by occasional air replacement, but some workers prefer to leave the fluid alone.

Remote effects

The ultimate results of large and persistent serous effusions may be thickening of the pleura, distortion of the mediastinum and atelectasis of the lung. Unfortunately many become purulent.

(b) Purulent

Treatment

Tuberculous empyema should be treated by frequent aspiration and lavage, as described below. If secondary pyogenic infection occurs, urgent and more frequent lavage is called for, and if the organism is sensitive, penicillin intrapleurally is invaluable.

(3) Air replacement of pleural effusion

Technique

If possible the patient should be in a sitting position. A Potain-type cannula is inserted through an interspace quite high in the axilla under local anaesthesia and, when through the pleura, pointed downwards. A pneumothorax needle connected to the refill apparatus is inserted close to the cannula and the intrapleural pressure observed. As fluid is aspirated, air is introduced through the needle slowly so as to attain the negative pressure required without undue tension on the lung.

Lavage

In purulent effusion uncomplicated by pleuro-bronchial fistula, lavage should be performed by running the solution through the aspirating cannula, adjusting the pressures as necessary by simultaneous removal of air. When the solution has been introduced, the patient should be placed lying down, and rolled slowly so as to allow contact with the whole pleural cavity. The procedure should be repeated until the fluid comes back clear, when about 200 cubic centimetres of the solution is left in the chest and the pressures are adjusted to a shade more negative than usual. Treatment on these lines, whether using dyes, azochloramid (to which a wetting agent may be added) or other solution, usually succeeds in overcoming the infection.

ASEPSIS AND ANTISEPSIS

By LAWRENCE P. GARROD, M.D., F.R.C.P.
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1. HISTORICAL

41.] The terms asepsis and antisepsis denote two policies or methods whereby the access of bacteria to wounds and their consequent infection is prevented. The supposed antithesis between them, such that they were represented in the past by two rival schools of thought, is based on a misapprehension; the two methods are complementary, having different indications and functions. The principles of asepsis have been accepted on all hands for many years, although there is still much to be learned about the details of their application; the only real dispute has concerned the scope and utility of the antiseptic method, and on this subject agreement is now almost general and a proper understanding certainly more widespread, owing to studies and discoveries made in the past few years.

2. ASEPSIS

(1) Definition

Asepsis may be defined as the exclusion of bacteria from the field of any surgical procedure by the previous sterilization of everything employed in it. This sterilization is usually carried out by heat, but even when a chemical method is employed for the disinfection of an instrument, the result is the same, and this should be regarded as an example of the aseptic technique.

(2) Pneumoperitoneum

With or without phrenic nerve interruption, pneumoperitoneum *may be* used before artificial pneumothorax when the disease is acute, or along with *artificial pneumothorax in the presence of uncontrolled disease in either or* both lungs.

(3) Oleothorax

It was claimed that Gomenol in oil was useful in empyema and for maintaining collapse in obliterative pleuritis. It is a dangerous procedure.

11. RESULTS

There are innumerable papers reporting the results of artificial pneumothorax treatment. Statisticians who have not differentiated the effective from the ineffective collapse are sceptical of its value. Clinicians have no doubt that an effective artificial pneumothorax, properly managed and combined with a sanatorium mode of life, is a life-saving measure; that some ineffective artificial pneumothoraces may be made effective by auxiliary procedures; and that an ineffective one is a danger.

[References to other titles are given under Pneumothorax in the Index Volume.]

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To secure satisfactory asepsis, attention has to be given to much besides such obvious possible sources of infection as the instruments used, and the hands and clothing of the operator.

(2) The air

Ventilation

Much septic infection is air-borne, and measures of several kinds are called for to prevent this. It is doubtful whether elaborate systems of ventilation, in which the air is washed or filtered, are necessary even for operating theatres; the outside air even of a city, if the intake or window is well above street level, is practically free from pathogenic bacteria. On the other hand, if any mechanical devices are employed for ventilation, the source and purity of the air introduced must be considered. It is a common practice to mount extraction fans in operating theatres, which are turned on to relieve excessive heat; the air so removed must be replaced, and the most free inlet is often under a door, with the result that the entry current carries floor dust with it. Dust is one source of air-borne infection; droplets expelled from the mouth or nose are another, and hence the wearing of masks by all personnel engaged in any surgical operation is a necessary precaution. The design of the mask is important; a few layers of gauze or other highly permeable fabric will not intercept all droplets, and the incorporation of a layer of totally impermeable material, such as Cellophane, is advisable.

Masks

(a) *Sterilization*

As a safeguard against air-borne infection in operating theatres, especially during prolonged operations involving the exposure of large areas of tissue, such as thoracoplasty, some surgeons have advised actual disinfection of the air by physical and chemical means. The chief advocate of ultra-violet light for this purpose has been Hart (1937, 1938), who exposes the field of operation directly to this form of irradiation, and claims thereby to have reduced the frequency of accidental infections, particularly by staphylococci. On the other hand, according to Devenish and Miles (1939), the number of pathogenic staphylococci recoverable from operating-theatre air is exceedingly small, and a common and much more prolific source of this organism is a minute perforation in the surgeon's glove, which allows sweat loaded with skin bacteria to escape. This is an alternative possibility which should always be borne in mind when such infections occur. Air disinfection is also feasible by chemical means, and of the several methods evolved recently the use of propylene glycol vapour appears the most promising; hitherto its use has been chiefly medical rather than surgical.

Ultra-violet irradiation

(b) *Hospital wards*

The problem of air-borne infection in wards is different and more pressing. Studies initiated by Cruickshank (1935), and pursued by (among others) White (1936), Miles and others (1940), Hare (1941) and Thomas (1941), have revealed that the dust of wards containing septic cases may be highly infective. This dust consists mainly of wool or cotton from blankets, sheets and other fabrics, which may be soiled by discharges or secretions, whether from wounds or from the upper air passages; it has repeatedly been shown to contain large numbers of haemolytic streptococci when this infection exists in the ward, and this organism can also be recovered from the air in greatly

Dust as important vector

Haemolytic streptococci

increased numbers after dust-raising procedures such as bed-making and floor-sweeping. In the hospital design of the future, this danger may be met by advanced methods of cleaning and ventilation aimed at the suppression of dust, but in the meantime much can be done in any hospital by adopting simpler precautions. Wounds are exposed to aerial infection only when they are being dressed, and dressings should therefore not be done in an open ward within one hour of bed-making or sweeping; better still, they should not be dressed in the open ward at all, but only after removal of the patient to a room reserved for the purpose. Alternatively, floor dust can be made to agglutinate in sticky non-dispersible masses by the treatment of the floor with spindle oil, according to van den Ende and Spooner (1941), Thomas and van den Ende (1941) and van den Ende and Thomas (1941). That these procedures will reduce the frequency of cross-infection, otherwise deplorably common in septic wards, has been amply proved.

(3) Contagion

The hands of the surgeon or nurse who has to deal with a succession of ward cases, whether in order to dress or merely to examine them, must unfortunately be recognized as still common vehicles of infection. Failure to appreciate that outer dressings which appear clean, and the skin at some distance from a wound, may both be heavily infected, is in part responsible for this. The "no-touch" technique of dressing is a valuable safeguard against this, and is fully described, together with many other items of modern aseptic ward technique in the Medical Research Council's *War Memorandum No. 6* (1942).

(4) Heat sterilization

Asepsis in both theatre and wards depends also upon the sterilization, usually by heat, of all the apparatus used in surgery, whether instruments, fabrics or fluids. Of the sterilization of gowns, towels, swabs, gloves and other items of equipment by autoclaving, it need only be said that the efficiency of this process should not be assumed, but proved by periodical tests in which packages containing heat-resistant spores are placed in the centre of drums and subsequently cultivated. Common causes of incomplete sterilization in the autoclave are over-tight packing of the contents of drums and insufficient air displacement.

Autoclaving

The absolute sterilization of instruments by heat is feasible by three methods; these are autoclaving, exposure to a temperature of 160° C. for one hour in a dry oven, or boiling for 5 minutes in water containing 2 per cent of sodium carbonate; without this addition boiling cannot be depended upon to destroy sporogenous bacteria. Preference among these methods varies in different countries; boiling is generally popular because it takes far less time. The use of dry heat is inexplicably neglected; instruments so sterilized in dust-proof containers can be kept indefinitely before use, and the method is ideal for all-glass syringes (Medical Research Council, 1945). No other procedure will serve for the sterilization of certain powders (dusting-powder for gloves, sulphonamide powders) or oils and similar substances (liquid paraffin, Vaseline, bone wax), because these cannot be penetrated by steam, or, if they can, are spoiled by it, as when sulphonamide powders are caked.

Instruments

Dry heat

Solutions

Distilled water, saline and other watery solutions used for surgical purposes should be autoclaved, and any remaining contents of each bottle after its first use should be discarded; only thus can contamination during use be guarded against. The immersion of various instruments in supposedly sterile distilled water, which was in fact contaminated, has led to frequent accidents; it is particularly dangerous when the instruments are those used for lumbar puncture (Smith and Smith, 1941).

(5) Chemical sterilization

Catheters

Certain instruments and other surgical materials cannot be sterilized by heat. This is true of some types of catheter, and of instruments used for various forms of endoscopy, since they are composed of or include materials which are spoiled by heat. Exposure to formaldehyde vapour is usually a satisfactory method of sterilizing such instruments, provided that penetration by the vapour is provided for; it cannot be depended upon to diffuse naturally into a narrow channel such as the lumen of a ureteric catheter. Solutions of chemical disinfectants may also be used for the storage of sterile materials in order to maintain their sterility; the choice of a reagent for this purpose depends rather upon its being innocuous to the material concerned than upon its merits as a disinfectant. Catgut presents a special problem; being derived from the small intestine of the sheep, it is liable to contain tetanus spores and, unless sterilized during the process of manufacture, is incapable of sterilization by any chemical means except immersion for seven days in Claudius's solution (iodine 1 gramme, potassium iodide 1·5 grammes, water 100 cubic centimetres). Post-operative tetanus has frequently been attributed in the past to raw catgut treated by methods which are demonstrably quite ineffective (Bulloch, Lampitt and Bushill, 1929).

Catgut

Claudius's solution

It should not be forgotten that antiseptics and disinfectants themselves are not necessarily self-sterilizing, and may convey infection unless freed from bacteria. This is true of sulphonamide powders, which are referred to above, of spirit, which has been known to contain living bacterial spores and should therefore be filtered, and particularly of preparations of penicillin, which have frequently been contaminated by bacteria resistant to its action, and so become vehicles of infection.

Self-sterilization not to be presumed

3. ANTISEPSIS

(1) Definition

The antiseptic method aims at erecting a chemical barrier between the tissues and the source of infection, whereas the aseptic method, where it is applicable, attacks the source itself. It consists of applying to some part of the body a chemical supposedly capable of killing or at least inhibiting the growth of bacteria, so that even should bacteria gain access to the body they will be prevented from attacking it. It is seen in its simplest form in Credé's method of preventing ophthalmia neonatorum. This consists of instilling silver nitrate solution into the conjunctival sac of the new-born infant; that this procedure has been successful is due to the great susceptibility of the gonococcus to chemical disinfectants, and to the fact that the application is made while the organism is still on the surface of the body and before it has been able to invade the tissues. The antiseptic method is also employed for the treatment,

by the application of chemicals, of infections already established; the term antisepsis will be understood here to include such procedures. It should not include the use of chemicals for sterilizing instruments and other items in the paraphernalia of surgery, since the aim of this procedure, as of disinfection by heat, is simply asepsis, that is, the sterility of everything employed.

(2) Theory

Whereas asepsis is the main safeguard of " clean " surgery, antisepsis is our only resource when bacteria have already gained access to the body. Apart from the limited possibilities of ultra-violet light, physical methods of disinfection are inapplicable when the tissues are concerned; a chemical method is the only feasible one. In order to define the uses and limitations of chemicals for this purpose, it is important to distinguish between three types of use. These are the disinfection of normal skin, the disinfection of a recent wound, and the treatment of established wound infection.

(3) Disinfection of normal skin

The disinfection of normal skin is by far the commonest application of the antiseptic principle in the whole of Medicine, preceding as it does every puncture for the injection of medicaments or the withdrawal of blood, as well as every incision at the start of a surgical operation. A great variety of disinfectants has been used for this purpose and an enormous literature exists on the subject. Much of this is difficult to interpret, owing to the diversity of the methods used, or valueless owing to their imperfections. For example, it has frequently been asserted that mercury salts actually render the skin sterile; in such experiments no steps were taken to neutralize the disinfectant in the material cultivated, and sterility was certainly due only to continued bacteriostatic action.

Mercury salt

To sterilize the skin completely is impossible. It harbours a resident flora composed of non-pathogenic staphylococci, diphtheroids and so forth, not only in the epidermal cells but in the sebaceous glands. All that is possible or necessary is to destroy the "transient" flora—possibly pathogenic bacteria which may have contaminated the skin surface but have not colonized it.

(a) *Iodine and spirit*

Several disinfectants have been proved to be capable of doing this. One is tincture of iodine; its drawbacks are expense and an irritant effect on delicate skins. Spirit alone is also effective; some of its modern advocates who adduce sound evidence in its favour are Hatfield and Lockwood (1943), Sobernheim (1943), Neufeld (1943), Neufeld and Schütz (1941) and Neufeld and Schiemann (1943).

(b) *Quaternary ammonium compounds*

Another and relatively new class of disinfectant is well suited to this purpose. These are the quaternary ammonium compounds of which the first Zephirol (Frankl, 1941; Gottsacker, 1942; Schumacker and Bethea, 1943), was introduced in 1935 by Domagk, the discoverer of Prontosil. There are now many such compounds available, including Cetavlon (Barnes, 1942; Williams and others, 1944), Ceepryn (Kramer and Sedwitz, 1944), Desogen (Grumbach, 1941) and Phemeride (Iland, 1944). A particularly valuable property of these substances is the persistence of their action; several of

Zephirol

these authors have found that when hands are so treated before donning rubber gloves the sweat contained in these gloves an hour or more later is sterile. The use of this type of skin disinfectant by surgeons should thus be a valuable safeguard against the contamination of operation wounds through glove perforations.

Spirit and dyes

These methods are to be preferred to the use of various older skin disinfectants; among the latter, mention should be made of alcoholic solutions of flavines and various antiseptic aniline dyes. To the immediate effect of spirit these add the more persistent antibacterial action of the dye, and they have the advantage of demarcating the area treated.

(4) Disinfection of recent wounds

To destroy or at least restrain the activity of bacteria in the cavity of a wound is much more difficult than to destroy them on the surface of the skin. They are less accessible, being enmeshed in blood-clot or situated in crevices, and the tissues exposed are far more susceptible to chemical damage than is the skin. The mere presence of blood or serous exudate is also an obstacle to antiseptic action; iodine and the halogens generally and many other disinfectants are inactivated by protein. A substance which is to serve as an antiseptic in a fresh wound must therefore retain its activity in the presence of blood, and must not unduly damage the tissues; it should also be penetrative and persistent.

Inactivation by protein

(a) *Older methods*

The neglect of these principles and the unintelligent use even of the few suitable antiseptics available in earlier times brought general discredit on the antiseptic treatment of wounds. It was argued that such treatment did more damage to tissues than to bacteria, and thus more harm than good. This was true of methods used as late even as World War I; strong solutions of phenol, cresol pastes and formalin were widely used, and the application of such grossly toxic materials can only be described as futile, and even barbarous. The properties of the older antiseptics and the reasons for their failure in combating wound infection are reviewed by Garrod (1940). There was in fact only one type of antiseptic in existence until recent times which possessed the qualities necessary for success in the prophylactic treatment of wounds. These were the flavines, which have been shown by abundant experimental evidence, reviewed by Browning (1929), to be capable of regularly preventing the development of infection when virulent bacteria are introduced into wounds or even injected subcutaneously. These observations were almost entirely ignored in this country for many years, and it was not until Albert and his collaborators (1938) resumed the study of the flavines, and Russell and Falconer (1941) demonstrated that a solution of proflavine could be applied to the exposed brain without causing undue damage, that interest in them began to revive.

Flavines

The antiseptic method, having been despised and rejected for a generation, returned fully to favour during World War II. This complete change of attitude has been due to the study of three classes of antiseptic, which are in fact the most useful for the purpose under consideration; these are the sulphonamides, the flavines and penicillin and other "antibiotics".

(b) Sulphonamides

Owing largely to ignorance of their mode of action, sulphonamides were little used as local antiseptics for four years after their introduction as systemic chemotherapeutic agents. Jensen, Johnsrud and Nelson (1939) were the first to introduce sulphanilamide powder into a series of wounds; they claimed thus to have reduced greatly the frequency of sepsis in compound fractures. The "powder" treatment of wounds was employed on a vast scale in World War II; the clearest of what little evidence there is of its effects is in Bentley and Thomson's study (1945) of 1,000 wounds sustained during the battle for the Gothic Line. All these received adequate surgical treatment; the preventive application of sulphanilamide in addition reduced the frequency of "infection"—meaning the presence, demonstrated by cultivation, of pyogenic bacteria—from 49 to 43 per cent, and of sepsis (clinical signs of infection) from 23 to 11 per cent. This is the sort of result to be expected; the sulphonamides are purely bacteriostatic agents, and are theoretically capable of suppressing the growth of bacteria without necessarily eliminating them. That they will prevent the development of gas gangrene if applied early enough has been shown experimentally by Hawking (1941) and McIntosh and Selbie (1942). In some circumstances they may be used alone; in others—notably the treatment of more dangerously contaminated wounds—they are probably better combined with one of the flavines or penicillin.

Meleney's conclusion (1945), on the basis of a large-scale statistical study, that sulphonamides either applied locally or given systemically do not reduce the frequency of wound sepsis must be mentioned; it is both theoretically inexplicable and contrary to other experience.

(c) Flavines

The capacity of the flavines to prevent wound infection, well attested by numerous experiments, can only be turned to full account by methods which have only recently been defined. Acriflavine, chiefly used in the past, has now no place in therapeutics; it is more toxic than other compounds and much too soluble. Proflavine (2 : 8-diaminoacridine sulphate) is preferable, or one of the newer compounds introduced by Albert, of which 2 : 7-diaminoacridine and 5-aminoacridine are best known. In order to secure a persistent effect it should be used in solid form. Since in fresh wounds undiluted proflavine powder has a toxic effect, it should be diluted with a sulphonamide powder; a mixture of one part of proflavine with 99 parts of sulphathiazole has been extensively used for war wounds, and is reported on favourably in both military and civil practice by Ascroft (1944), Feggetter (1944) and McIntosh and Selbie (1944). A chemical combination of these two substances, known as Flavazole, appears to combine their virtues and may be similarly used according to McIntosh, Robinson and Selbie (1945).

Disadvantages of acriflavine

Proflavine

Combination with sulphonamides

(d) Penicillin

All other advances in antiseptic technique have been overshadowed during the latter part of World War II by the astonishing achievements of penicillin. Such of these as result from its systemic use are outside the scope of this article, but penicillin also has ideal qualities for use as a local antiseptic. In several studies already quoted the best results were achieved with it; for the prevention of experimental gas gangrene McIntosh and Selbie (1942) found

the order of merit to be penicillin, proflavine, sulphanilamide; in Bentley and Thomson's study in 1945 of war wounds in Italy, penicillin and sulphathiazole powder was more effective than sulphanilamide in reducing the frequency of sepsis and much more so in actually eliminating pathogenic bacteria. For purely prophylactic use, insufflation with a powder containing 2,000 or 5,000 units of calcium penicillin per gramme of sulphanilamide or sulphathiazole is the method of choice.

Combination with sulphathiazole

(5) Treatment of septic wounds

There is a profound difference, largely ignored in the past, between preventing wound infection by antisepsis and treating it. In the former case, the contaminating bacteria are in the wound cavity, and hence more or less accessible according to the shape of the wound and the disposition of the tissues bordering it; there they are known to remain for two hours before beginning to multiply and migrate. In established sepsis, on the other hand, the bacteria are actually in the surrounding tissues and thus far less accessible, as well as being much more numerous. If the tissues are being deeply invaded, as in spreading cellulitis or gas gangrene, local applications to the wound must be useless. Local sepsis, however, is sometimes amenable to antiseptic treatment; much depends upon the nature of the infection, haemolytic streptococci and staphylococci, particularly the former, being highly susceptible to antiseptics, whereas *Proteus*, *Pseudomonas pyocyanea*, and other Gram-negative bacilli are much more resistant.

Accessibility

Deep invasion

Local sepsis

(*a*) *Flavines*

Sulphonamide powders are much less effective in suppurating than in fresh wounds, because pus contains breakdown products which neutralize their action. The flavines, on the other hand, have an important use if properly applied. Proflavine was first used in powder form for the treatment of intractable wound sepsis by Mitchell and Buttle (1942); these authors (1943) also reported favourably on diflavine (2 : 7-diaminoacridine) for this purpose; others who have used proflavine similarly and successfully are Raven (1944) and Heggie, Warnock and Nevin (1945). The principles underlying this treatment need to be understood. Infected granulation tissue bathed in pus is much less susceptible to the toxic action of proflavine than are the tissues bordering a recent wound; the powder can therefore be applied undiluted, but the quantity used should not exceed 0·5 gramme, and less is required for smaller wounds. Proflavine, not being highly soluble (solubility 1 in 300), dissolves slowly and exerts an effect for hours, or even days, if the wound is enclosed. That wounds so treated often cease to discharge and proceed to heal is clear from the experience of the writers quoted. Vigorous attack on chronic sepsis by the use of acridines is advocated also by Poate (1944); he uses 5-aminoacridine in the form of a solution continuously introduced through tubes, or of an emulsion.

Infected granulation tissue

(*b*) *Penicillin*

Penicillin is entirely non-toxic, and acts as well in the presence of pus as in a fresh wound; on the other hand, it not only has no action on the various Gram-negative bacilli which infect wounds but is often destroyed by them. It is thus the ideal antiseptic only for wounds infected by streptococci and staphylococci. With this proviso its merits are unequalled and its uses

Gram-negative bacilli

manifold. In solution, or in the form of a powder diluted with a sulphonamide, or as a cream, it has been successfully used in treating wounds of many kinds: burns; abscesses; infections of serous sacs, joints and the meninges, and of the eye, mouth and throat and skin.

The problem of "Gram-negative infection", on which penicillin has no action, has not yet been altogether overcome. The flavines are effective against it to some extent, and claims in this direction have been made for Phenoxetol, and for microbic extracts other than penicillin (gramicidin or tyrothricin, streptomycin and so forth). The merits of these agents have yet to be assessed.

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[References to other titles are given under Asepsis and Antisepsis in the Index Volume.]

ASYMMETRY

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1. INTRODUCTION

42.] As many lower forms of life show radial symmetry, so the higher forms show bilateral symmetry—a requirement for efficient locomotion whether in fish, fowl or beast or in such creations of man as ship, aeroplane or car. Granted preservation of balance, visceral symmetry is unnecessary; that of the lower types and of the embryo is greatly modified in the higher adult.

Bilateral symmetry

2. AETIOLOGY

Even outer symmetry is never perfect. The girth of the right arm exceeds that of the left in the right-handed. Often one limb is longer than its fellow by part of an inch, without symptoms. Sometimes one side of the body slightly exceeds the other. The excess of a member may amount to local gigantism, either without known cause or associated with a diffuse neurofibromatous condition (Fig. 210) or angioma; it may be the result of an arteriovenous communication. (*See* p. 363.)

Physiological asymmetry

Shortening may result from developmental anomalies (Fig. 211), such as congenital pseudarthrosis or bowing of the tibia, phocomelia (developmental deficiency of limb segments proximal to hand or foot, so that hand or foot arises abnormally near trunk), infantile coxa vara, or congenital dislocation of the hip. Some general bony conditions, chiefly affecting one side, may produce unilateral stunting (fibrosis of bone, Ollier's dyschondroplasia).

Developmental anomalies

Diminished growth of a limb often results from deficient circulation, commonly due to limited use, and particularly notable in lower motor neurone paralysis. The discrepancy between the vascularity of active and inactive muscles is very great, but trophic changes are not always proportionate to the paralysis. Diminution of growth is much less in upper motor neurone paralysis.

Diminished circulation

Trauma may cause shortening through tissue loss, malunion, or injury to the growth plate. Epiphyseal separation rarely arrests growth, but fracture through the epiphyseal plate often does. Fracture remote from this

Injury

sometimes stimulates overgrowth. Excessive traction also may cause lengthening after fracture.

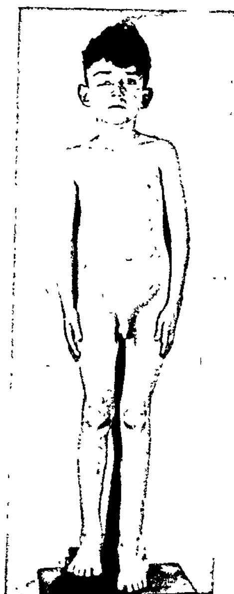
Inflammation Inflammatory changes occasionally stimulate growth, but more commonly cause shortening by diminution of epiphyseal growth, bony destruction, dis-



(*a*)



(*b*)



(*c*)

FIG. 210.—(a) Gigantism of toes, cause unknown; (b) and (c) overgrowth of left leg in a case of neurofibromatosis.

location, or a combination of these as in loss of the femoral head from acute epiphysitis of infancy ("Tom Smith's disease").

3. INVESTIGATION

It should be determined (a) whether asymmetry is present, (b) its extent, (c) its cause (if ascertainable), (d) its effects on well-being.

(1) History

Parental observation

Attention may be attracted by a limp; by scoliosis, with perhaps backstrain; or by disproportion between opposite parts. *A parent's observation must never be disregarded.* (On the other hand, an offspring's mirror image may convince an unperceiving parent.)

(2) Clinical examination

Local

In most cases, orthodox inspection of both sides of the body together reveals the asymmetry. Mensuration should distinguish real from apparent shortening, determine its site and register girth.

General

The circulatory and neuromuscular condition of the part, and its mobility, should be examined. The other limbs, the back, the gait, the general condition and the mentality should not escape attention.

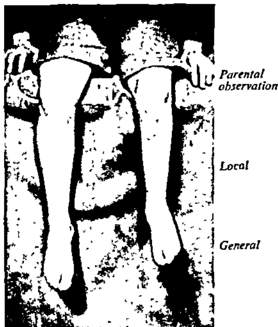


Fig. 211.—Deficient growth of left leg and foot in a case of (corrected) congenital talipes equino-varus.

(3) Special examination

Radiography

Radiography is most important. *Asymmetry of an infant's lower limbs, or a limp, demands radiography of the hips,* lest the time for treating congenital subluxation or dislocation should pass for ever.

4. TREATMENT

Prophylaxis

Eugenics apart, prevention is favoured by efficient diagnosis and treatment of injuries, inflammatory conditions and congenital defects.

Management of the established condition may be (a) without treatment, (b) conservative or (c) operative.

(1) No treatment

Upper limb

In the upper limb none is required except (a) cosmetic operations, (b) treatment of associated defects, such as unequal radial and ulnar growth.

Lower limb

In the lower limb, differences of one inch and sometimes more can be disregarded if, in children, the back is watched; the scoliosis rarely becomes structural unless asymmetry is complicated, as by ankylosis or paralysis.

(2) Conservative treatment

Shortening is partially compensated by increasing the height of the shoe.

(3) Operative treatment

Plastic surgery

Plastic operations may be needed.

Osteotomy

Shortening with ankylosis of the hip can be compensated by abduction osteotomy; if shortening is excessive, compensation should be partial. If ankylosis is fibrous, and recurrence therefore possible, the lower fragment

should be displaced inwards after osteotomy opposite the lower acetabular margin, with radiographic control of level and direction during operation.

Equalization of limb length is possible: (a) in adults and children, by (i) lengthening the shorter, (ii) shortening the longer ; (b) in children only, by (i) accelerating growth of the shorter, (ii) diminishing growth of the longer.

Leg lengthening

The shorter limb being usually at fault, hypothetically this should be lengthened. Case selection, operation and after-care are beset by pitfalls, and are for the experienced only. Modern trends are towards lengthening before correction of deformities, double transfixion of each fragment, simplicity of osteotomy and minimal division of soft tissues.

Leg shortening

To shortening the longer limb, if normal, there are two objections—stunting of the patient, and surgical adventure with the good leg.

Stimulation of growth

Thanks to improved circulation, lumbar sympathectomy accelerates growth (above the rate of its healthy fellow) in a limb stunted by infantile paralysis—rarely a worthwhile procedure, especially if paralysis is extensive.

Suppression of growth

The objections to leg shortening apply also to diminution of growth by epiphyseal disc destruction, which, moreover, lacks precision and may cause deformity from incomplete arrest.

Amputation

Amputation sometimes offers the best functional solution of gross shortening and deformity.

[References to other titles are given under Asymmetry in the Index Volume.]

AUTONOMIC NERVOUS SYSTEM: INTRODUCTION

By J. PATERSON ROSS, M.S., F.R.C.S.
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1. SYMPATHETIC AND PARASYMPATHETIC SYSTEMS

Sympathetic and parasympathetic components, in balanced activity

43.] The autonomic nervous system has two components, the thoraco-lumbar or sympathetic, and the cranio-sacral or parasympathetic systems. Since the effects of sympathetic and parasympathetic impulses are frequently antagonistic, the function of many viscera innervated from both sources is controlled by their balanced activity. A disorder of function which indicates excessive activity of one portion of the autonomic system presents to the surgeon an opportunity of attempting to restore the balance by interrupting the pathway of the superfluous impulses.

Surgery of the sympathetic nervous system

Thus far the disorders so treated have been manifestations of excessive sympathetic activity; and except for a few operations on the vagus nerve and on the carotid sinus, the surgery of the autonomic nervous system as we know it today means the surgery of its sympathetic portion. It must be noted, however, that the indications for sympathectomy are not strictly limited to conditions of sympathetic overactivity, but include the palliation of any disease in which the abolition of normal sympathetic control would be an advantage, and the treatment of certain forms of intractable pain.

"Surgery of function"

The surgery of injury, infection or new growth aims at complete restoration to the "normal"; the effects of sympathectomy upon disordered visceral function must be expressed in terms of improvement rather than cure. Even when the operation has been a perfect anatomical procedure function may not be normal, either because of some original constitutional defect, or because a long-standing or severe functional disorder may have resulted in structural disease—for example, megacolon may be complicated by fibrosis and ulceration, or Raynaud's disease by obliterative arteritis. The nearest approach to cure by sympathectomy is achieved in the treatment of hyperhidrosis.

Transient effect of operation

Sympathetic denervation by a well-planned and correctly executed operation is permanent, yet it is commonly supposed that the effects last for only a few months. This mistaken opinion is explicable on three grounds. Sometimes the operation may have been incomplete, and because of the physiological

provision for a wide distribution of sympathetic impulses, even a few filaments which escape division can be responsible for widespread manifestations of sympathetic activity. Another reason is that after a period of profound sympathetic paralysis many organs seem to be able to work in an apparently normal manner without sympathetic control. The establishment of this independent function may be misinterpreted as evidence that the sympathetic is still in action. The most important explanation is that the operation may have been performed for the palliation of a progressive disease, and though sympathetic denervation be complete and permanent, the advance of structural disease may prove to be overwhelming, for example in the obliterative arteritis of Buerger's disease. (*See* p. 482.)

The tendency of surgeons seeking to explain poor results of sympathectomy has been to over-emphasize the anatomical imperfection of a particular operation, and to introduce modifications which involve the indiscriminate removal of more and more of the sympathetic system. It is preferable by anatomical research to determine the resection which will denervate the affected part with the minimum of disturbance in its neighbourhood, but above all to concentrate attention upon the selection of patients for operation, so that those may be excluded whose diseases cannot be expected to respond to sympathectomy.

Care in selection of patients for operation

The anatomy of the autonomic system will be described in detail (*see* p. 452) but it would be out of place in this work to include an exhaustive account of its physiology and pharmacology. Brief references to the principles which have a bearing upon surgery must suffice.

(1) Blood-vessels

Vasomotor control of small arteries

The minute vessels

Vasoconstrictor fibres supply all the limb arteries, the cerebral and retinal arteries, and those in the splanchnic area. They can be traced to the capillaries, but the minute vessels are controlled also by chemical agents. Vasoconstrictor nerves act upon small arteries, of the size of the palmar and plantar arches and their digital branches. Blood flow in these arteries affects the temperature of the skin; the calibre of the minute vessels (arterioles and capillaries) influences its colour, which is red or blue when they are dilated, and pale when constricted. Immediately after the vasoconstrictor impulses have been blocked by sympathectomy the skin becomes warm and red owing to paralytic dilatation of both groups of vessels. But within a few days the denervated extremity, while remaining warm owing to the persistent arterial dilatation, becomes pale through constriction of the minute vessels. The pallor of the warm limb can be explained by the return of tone to the arterioles and capillaries, since denervation renders them more sensitive to the constrictor effect of adrenaline.

Effects of sympathectomy

Persistence of chemical control

Only one smooth-muscle cell in a hundred receives a nerve ending, the impulse being distributed throughout the organ by means of sympathin, a chemical substance discovered by Cannon, which is liberated at sympathetic nerve endings. This chemical mediation of nerve impulses is of fundamental importance in surgery, since it explains the futility of an incomplete sympathectomy. Furthermore, it must be remembered that after sympathetic denervation smooth muscle becomes more sensitive to this chemical stimulation. Since sympathin and adrenaline are nearly identical in their pharmacological

Chemical mediation of nerve impulses

Sensitization of denervated muscle

actions it is clear that both denervated small arteries and minute vessels will show an increased sensitivity to circulating adrenaline. Freeman, Smithwick and White (1934) have shown that exposure to cold can cause an outpouring of adrenaline sufficient to produce vasoconstriction in the human hand after sympathectomy. Finally, it is of importance in planning surgical procedures to know that this sensitization of the vessels to adrenaline is less after pre-ganglionic than after post-ganglionic section.

Sensitization less after pre-ganglionic section

Though these responses to chemical stimulation are of much interest and importance they must not be over-stressed. With theoretical considerations alone to guide us we might conclude that sympathectomy must produce vasoconstriction! It is fallacious to regard the vasomotor responses observed in Raynaud's disease as being typical of the physiological effects of sympathectomy, since the vasomotor control was abnormal before the vessels were denervated. There is no doubt that the limb of a person whose vessels are not diseased will remain warm for an indefinite period after sympathectomy, paralysis of vasoconstriction having a predominant effect on the arteries.

The sympathetic system sends vasoconstrictor fibres to the veins also, and dilatation of the superficial veins after sympathectomy is a constant feature, though it is naturally more noticeable in the lower extremity.

Vasomotor fibres to veins

It has usually been taught that sympathetic impulses produce dilatation of the arteries in skeletal muscle, and that there is a reciprocal relationship between the blood flow to the skin and to the muscles of a limb, sympathectomy increasing the blood supply of the skin while decreasing that to the subjacent muscle. It is well recognized that intermittent claudication resulting from muscle ischaemia sometimes persists after sympathectomy in spite of an improvement in the cutaneous circulation, and it has been suggested that this is only to be expected on physiological grounds.

Arteries in skeletal muscle

Intermittent claudication

Recent observations by Barcroft and his colleagues (1943) indicate that the vessels in human skeletal muscle receive sympathetic vasoconstrictor fibres, and their experiments are in accord with much of our clinical experience. Many patients have been relieved of intermittent claudication by sympathectomy, and when seeking to explain the failures it must be remembered that the vascular disease which caused the symptoms may not only have done irreparable damage to the muscle, but also may have produced such profound changes in certain important arteries that the laws of physiology can scarcely be applied to the problem. If, for example, the sural arteries have been blocked by thrombosis the very meagre collateral circulation in the calf muscles cannot provide a blood supply to the ischaemic part sufficient to prevent the pain of intermittent claudication.

Obliterative arteritis

(2) Heart

Sympathetic impulses quicken the heart beat, though under normal conditions they seem to play but a minor part in the regulation of the pulse rate.

Pulse rate

Though it is not universally accepted, the balance of the evidence favours the view that sympathetic vasomotor impulses dilate the coronary arteries. Since sympathetic activity is associated with enhanced bodily or mental activity an increase in cardiac output is called for, and it is therefore natural that there should be at the same time an enhanced blood flow to the heart muscle.

Coronary circulation

(3) Lungs

Bronchial asthma

Stimulation of the vagus causes constriction of the bronchi, and once more the sympathetic has an antagonistic effect which is demonstrated clinically in the treatment of bronchial asthma by adrenaline. There seems to be no physiological support for the treatment of asthma by sympathectomy, though improvement has been reported by several observers. The suggestion has been made that the successes may have resulted from the sensitization of the denervated bronchi to adrenaline, but there is little to support this hypothesis, and it must be remembered that many operations have been undertaken without success.

(4) Alimentary canal

Cardiospasm

Antagonism between the vagal and sympathetic innervation of the oesophagus has been clearly demonstrated in animals, and a condition closely simulating cardiospasm has been produced by bilateral vagectomy (Knight, 1934). In spite of these promising experimental findings attempts to treat cardiospasm by sympathectomy have given variable and disappointing results, partly perhaps because of difficulty in devising an operation which will ensure the complete sympathetic denervation of the oesophagus.

Stomach and intestine

While there can be no doubt that the vagus and sympathetic nerves are the pathway for the nervous control of motor and secretory activity in the stomach and small intestine, being involved especially in their responses to the thought, sight, smell and taste of food, and in the reactions to emotion, it has not been possible to recognize a disorder of these organs which might reasonably be treated by abdominal sympathectomy.

Megacolon

In the colon, however, it has been established by clinical observation and animal experiment that megacolon may be the result of insufficiency of the sacral autonomics (Adamson and Aird, 1932). Stimulation of the sympathetic nerves to the colon and rectum produces relaxation of the muscle coats of these viscera with simultaneous contraction of their sphincters, and an increase in the motor activity follows interruption of the sympathetic supply. When all the extrinsic nerves to the colon have been paralysed by a spinal anaesthetic motor power in the gut is preserved and even becomes more vigorous, which indicates that the function of these nerves is merely to regulate the activity of the intrinsic nerve plexuses. It may be that achalasia of the cardia and also of the pelvi-rectal sphincter results from a disorder in the controlling function of the sympathetic and parasympathetic nerves; it is remarkable that megacolon has been treated successfully by producing a temporary paralysis of these nerves by spinal anaesthesia. When the viscus has recovered from the effect of the anaesthetic the normal control has been restored (Telford and Simmons, 1939; Hawksley, 1944).

Effects of spinal anaesthesia

(5) Genito-urinary system

Parasympathetic control of bladder

Though it was believed at one time that the sympathetic-parasympathetic antagonism also regulated the movements of the urinary tract, more recent research indicates that the whole mechanism of micturition is controlled entirely by parasympathetic nerves, and that sympathetic impulses play no part in the movements of the ureter. (*See* article on Bladder—Neurogenic Disturbances.)

Stimulation of the superior hypogastric plexus (presacral nerve) causes the

seminal vesicles to empty (Learmonth, 1931) and this suggests an explanation for the observation that men who have undergone presacral neurectomy or bilateral lumbar ganglionectomy may be sterile. Learmonth believes that it is removal of the first lumbar ganglion which has this effect, though it has been observed after operations in which the resection has not gone higher than the second ganglion. There is good clinical evidence that the defect may be temporary, and that it is not a constant feature even after bilateral removal of the upper lumbar ganglia. Though a patient must be warned of the possibility of sterility as a result of the operation, the risk may well be accepted if the condition to be treated threatens the vitality of his limbs, or handicaps him seriously in his work.

Sterility after sympathectomy

While sympathetic impulses are known to cause contractions of the uterus, it has long been recognized that menstruation and parturition can occur normally after excision of the superior hypogastric plexus.

Uterus

(6) Visceral pain

Most of the nerves which supply the thoracic and abdominal viscera arise as branches of the sympathetic trunks, and it may therefore be inferred that sympathetic nerves must convey sensory as well as motor impulses. It is now known that fibres which are comparable in all respects with somatic afferents, having their cells in posterior root ganglia, are bound up with the sympathetic visceral nerves and provide the actual pathway for pain sensation from viscera. (*See* Fig. 213.) These fibres which accompany sympathetic nerves are functionally quite separate from the sympathetic system, which itself takes no part in the conduction of pain. These anatomical and physiological features are exemplified in the pain of angina pectoris (*see* p. 255) and explain the relief of visceral pain by sympathectomy.

Afferent fibres accompanying sympathetic visceral branches

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[References to other titles are given under Autonomic Nervous System in the Index Volume. The subject of Sympathetic and Parasympathetic Nervous System is also dealt with in the *British Encyclopaedia of Medical Practice* (1938), Vol. 11, p. 503.]

AUTONOMIC NERVOUS SYSTEM: ANATOMY

By A. DURWARD, M.D., F.R.S.E.
Professor of Anatomy, University of Leeds

1. INTRODUCTION

Parasympathetic

Sympathetic

44.] The autonomic system consists of two parts, the sympathetic and the parasympathetic, which differ functionally and in their reactions to various drugs. Developmentally both are outposts of the central nervous system and are always linked with the latter by both afferent and efferent fibres. The parasympathetic system is connected with the cerebrospinal axis in the cranial and sacral regions by what is known as the cranio-sacral outflow; the sympathetic system is linked with the cord (from the first thoracic to the second or third lumbar segments) by the thoraco-lumbar outflow. In both systems, the dominant structural distinction is the presence of the excitor neurone in a peripheral position, generally in a ganglion or in a ganglionated plexus. For this reason the neurones which link the cerebrospinal axis with such excitor neurones

outside it are called pre-ganglionic, while the excitor neurones themselves are post-ganglionic. Pre-ganglionic fibres are usually medullated whilst the post-ganglionic axons are non-medullated. The post-ganglionic neurones are much more numerous than the pre-ganglionic—an arrangement which favours diffusion of effects. (*See* Fig. 212.)

Pre-ganglionic and post-ganglionic neurones

It is expedient today to regard the autonomic system as possessing, in addition to the classically defined efferent mechanism, splanchnic afferent fibres which carry impulses to the cord and the brain from visceral fields, for example the heart, blood-vessels, lungs, gut and genito-urinary organs. Although

Splanchnic afferent fibres

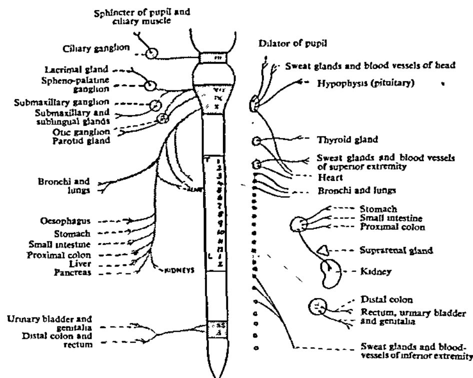


FIG. 212.—General scheme of the autonomic system; sympathetic on right, parasympathetic on left.

these impulses generally do not excite any conscious state, they form the afferent side of various reflexes. They behave much as do ordinary somatic afferents by entering the cord via the dorsal nerve roots (or by way of the cranial nerves) and their cell bodies lie in the dorsal root ganglia or in their cranial counterparts (*see* Fig. 213).

2. SYMPATHETIC SYSTEM

The most obvious feature of the sympathetic system is the longitudinally arranged sympathetic trunk, composed of the paravertebral ganglia and their interconnecting strands of fibres. In development, one ganglion is associated with each emerging spinal nerve, but in some regions early fusion of adjacent ganglia has reduced the number. Three ganglia are associated with the

The paravertebral ganglia

AUTONOMIC NERVOUS SYSTEM: ANATOMY

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PROFESSOR OF ANATOMY, UNIVERSITY OF LEEDS

1. INTRODUCTION

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Parasympathetic

Sympathetic

above or below the limits of the thoraco-lumbar outflow, namely above the first thoracic and below the second or third lumbar segments.

(1) Cervical trunk

The cervical part of the trunk lies on the prevertebral muscles and behind the carotid vessels. Superiorly it continues into the cranium as the internal carotid plexus and inferiorly it is continuous with the thoracic part of the trunk in front of the neck of the first rib. The superior cervical ganglion is an elongated fusiform structure, about one inch in length, lying behind the neuro-vascular bundle formed by the internal carotid artery, the internal jugular vein and the last four cranial nerves. It is adherent to the fascia covering the

Superior cervical ganglion

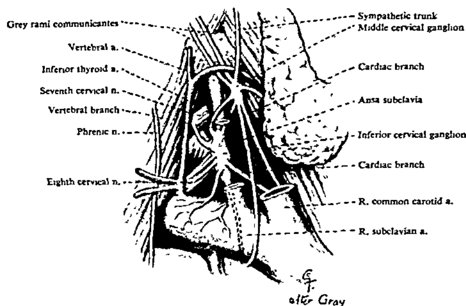


Fig. 214.—The inferior and middle cervical ganglia of the right side; the internal jugular vein is not shown, and the vertebral and common carotid arteries are partly removed.

longus capitis muscle. Above, it reaches to within two centimetres of the entrance of the carotid canal, and below to about the level of the angle of the jaw. The middle cervical ganglion is the smallest and the most variable of the cervical ganglia. It may not be recognizable, or it may be greatly reduced in size owing to complete or partial fusion with the inferior ganglion. Its most usual position is in front of or behind the inferior thyroid artery as the latter passes between the common carotid artery and the sixth cervical transverse process. Occasionally it occupies a lower position close to the vertebral artery.

The inferior cervical ganglion is a large irregularly shaped mass formed in development by fusion of the lower two (or more) cervical segmental ganglia and commonly the first—or maybe the first and second—thoracic ganglia as well. In the latter case the term stellate ganglion is applied to the fused mass. Lying at the cervico-thoracic junction, where the trunk presents a marked change in direction, the long axis of the ganglion lies almost antero-posteriorly.

Stellate ganglion

cervical nerves, ten or eleven with the thoracic, four with the lumbar and four with the sacral nerves. Caudally, the two trunks unite in front of the coccyx where a median ganglion impar may be found. At the cephalic end, each trunk is continued into the cranium as the internal carotid plexus.

Pre-ganglionic fibres emerge from a sharply defined *region of the cord. From* the first thoracic to the second or third lumbar segment each ventral nerve

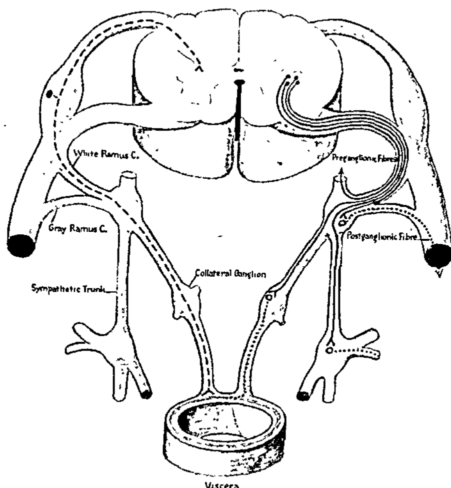


FIG. 213.—The disposition of pre-ganglionic and post-ganglionic fibres of the sympathetic trunk, and the pathway of visceral afferent fibres.

White rami communicantes

root carries out medullated pre-ganglionic fibres—axons of cells located in the lateral grey horn of the cord. (*See* Fig. 213.) These fibres leave the corresponding anterior primary ramus as fine bundles, called the white rami communicantes, and join the sympathetic trunk. They may join the immediately adjacent *ganglion or they may course up or down to reach ganglia* of the cervical, lumbar or sacral regions. Many of the fibres comprising the rami end around post-ganglionic neurones in the ganglia of the trunk, but others pass through these ganglia to be distributed to more peripherally placed collections of post-ganglionic neurones. There are no white *rami communicantes*

above or below the limits of the thoraco-lumbar outflow, namely above the first thoracic and below the second or third lumbar segments.

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Superior cervical ganglion

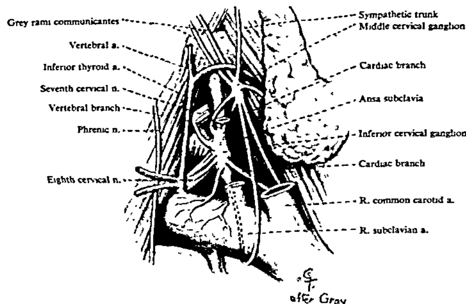


FIG. 214.—The inferior and middle cervical ganglia of the right side; the internal jugular vein is not shown, and the vertebral and common carotid arteries are partly removed.

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The inferior cervical ganglion is a large irregularly shaped mass formed in development by fusion of the lower two (or more) cervical segmental ganglia and commonly the first—or maybe the first and second—thoracic ganglia as well. In the latter case the term stellate ganglion is applied to the fused mass. Lying at the cervico-thoracic junction, where the trunk presents a marked change in direction, the long axis of the ganglion lies almost antero-posteriorly.

Stellate ganglion

The ganglion occupies a space bounded in front by the vertebral artery near its origin from the subclavian artery, below by the dome of the pleura and dorsally by the neck of the first rib and the seventh cervical transverse process. The antero-superior pole of the ganglion may lie in front of the vertebral artery and may be joined to the remaining and major part by nerve strands encircling the artery. This is known as the *ganglion intermédiare* and is due to a fusion of some part of the middle with the inferior ganglion. Linking the middle and inferior ganglia is the usual interganglionic trunk which lies in a plane behind the subclavian artery; in addition a bundle of fibres loops down in front of the subclavian artery to form the ansa subclavia.

(2) Thoracic trunk

The thoracic trunk descends under cover of the pleura in front of the intercostal vessels. In the upper thorax it lies on the necks of the ribs but, traced downwards, it comes to lie over the costo-central joints, and in the lowest levels medial to the joints on the sides of the vertebrae. It presents ten or eleven ganglia with interganglionic trunks of considerable thickness. At the cervico-thoracic junction the trunk is directed rather backwards, and at this level the first thoracic ganglion, and may be the second as well, is not infrequently fused in a common mass with the inferior cervical (stellate) ganglion. At its lower end the thoracic trunk passes behind the medial arcuate ligament to enter the abdomen.

(3) Lumbar trunk

The lumbar trunk extends downwards on the bodies of the lumbar vertebrae medial to the psoas muscle, and is overlapped on the right by the vena cava and on the left by the aortic lymph glands. It lies in front of the lumbar vessels; some lumbar veins, however, may pass anteriorly. Inferiorly the lumbar chain continues into the pelvis behind the common iliac artery. Usually there are four ganglia, but variation is not uncommon.

The lumbar trunk is separated from the spinal nerves by the massive psoas muscle, and this leads to a considerable increase in the length of the rami communicantes as compared with that of the thoracic rami communicantes. Only the upper two (or three) lumbar nerves send white rami to the trunk; not infrequently these are intermingled with the grey rami.

(4) Sacral trunk

The sacral trunk lies on the pelvic surface of the sacrum, commencing deep to the common iliac vessels and extending downwards and somewhat medially. The trunk is disposed medial to the upper sacral foramina; at the level of the fourth it lies in front of the foramen and overlaps the fourth sacral nerve. Below this the two trunks end either in a median ganglion impar in front of the coccyx or as a few intercommunicating strands.

3. BRANCHES OF DISTRIBUTION FROM THE SYMPATHETIC TRUNK

The branches of distribution from the sympathetic trunk may be classified under three headings. (1) Branches accompanying nerves. These are mainly grey rami communicantes, and also the fibres joining certain cranial nerves. (2) Branches accompanying the main vascular trunks, but not extending far

along their branches. The more peripherally placed vessels receive their nerve supply from adjacent peripheral nerves by fibres which have previously joined the latter as grey rami communicantes. (3) Direct visceral branches. Each region of the chain gives branches which proceed to viscera, generally after passage through a plexus. These visceral branches are composed of an admixture of fibres: pre-ganglionic which will meet their excitor neurones in a plexus, post-ganglionic from neurones of the sympathetic trunk and visceral

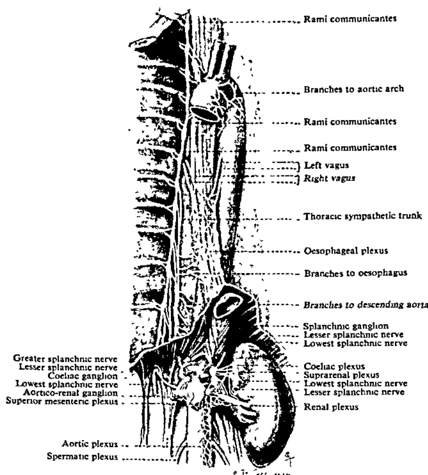


FIG. 215.—The autonomic nerves and plexuses of the thorax and the upper abdomen.

afferent fibres. The various visceral branches and their associated plexuses are to be regarded as a system of ganglionated plexuses.

(1) Accompanying nerves

In the cervical region the ninth, tenth and twelfth nerves receive branches from the superior ganglion, while from the inferior ganglion twigs join the recurrent laryngeal nerve.

Grey rami communicantes

Every spinal nerve, from the first cervical to the coccygeal, receives a grey ramus communicans composed of post-ganglionic neurones. In the cervical

region rami from the superior ganglion join the first four spinal nerves, from the middle ganglion the fifth and sixth, and from the inferior ganglion the seventh and eighth spinal nerves. Below this the arrangement is more regular, although it is not at all uncommon to find rami proceeding to a spinal nerve from two adjacent sympathetic ganglia; further, in the thoraco-lumbar region where white rami are also present the two types of rami may be intermingled. The fibres of the grey rami then proceed in the spinal nerves to provide the body wall and limbs with their vasomotor, sudomotor and pilomotor supply.

(2) Vascular branches

There are many such branches, and as a rule they take their names from the blood vessels which they accompany. Many of them are undoubtedly vasomotor (and vasosensory) but others merely accompany the vessels to reach other than vascular fields of distribution. From the cervical chain, branches accompany the internal and external carotid arteries, and also supply the carotid body, the thyroid gland and the vertebral and subclavian arteries. Among the fibres accompanying the internal carotid are those post-ganglionic fibres from the superior cervical ganglion which ultimately reach the radial muscle-fibres of the iris (dilator pupillae). Their pre-ganglionic counterparts emerge from the cord in the first thoracic nerve, having arisen from the ciliospinal centre in the lateral grey horn at that level. In the thoracic and lumbar regions, vascular branches supply the aorta and the adjacent parts of blood-vessels arising from it.

Pupillo-dilator pathway

(3) Visceral branches

Visceral branches are given from each level of the trunk, and in general these descend to reach a field of distribution somewhat below their level of origin.

(a) Cardiac nerves

From the cervical trunk the cardiac nerves descend to the thorax where they end in the cardiac plexuses. Each cervical sympathetic ganglion gives such a branch—but all these nerves are not of equal functional value; the superior cardiac sympathetic nerves are purely efferent while the others are both efferent and afferent. These cervical cardiac branches are distributed, along with vagal fibres, to the cardiac and coronary plexuses and thence to the heart and lungs and the associated vessels. (*See* p. 255.)

(b) Splanchnic nerves

From the thoracic trunk, apart from some few pulmonary and cardiac branches about the level of the second, third and fourth ganglia, the main visceral nerves are the three splanchnic nerves which descend to the abdomen. The greater splanchnic nerve arises from the trunk between the fifth and the ninth (or tenth) ganglia, the lesser from the ninth and the tenth and the lowest (which may not exist as a separate nerve) from the last thoracic ganglion or from the lesser splanchnic nerve. All are to be regarded as ganglionated plexuses, and the contained fibres may be either pre-ganglionic or post-ganglionic, or again they may be splanchnic afferent fibres. Cell bodies are found scattered here and there amongst the fibres or are occasionally aggregated as an obvious ganglion—for example the splanchnic ganglion on the greater nerve.

(c) *Coeliac plexus*

The splanchnic nerves enter the abdomen through the corresponding crus of the diaphragm and shortly end in the coeliac plexus. This is a large accumulation of nerve fibres and ganglion cells disposed on the dorsal abdominal wall in relation to the aorta at the level of the twelfth thoracic and the first lumbar vertebrae. Three large aortic branches arise here and have some importance in the morphology of the plexus: the coeliac axis, the superior mesenteric artery and the renal arteries. Within the plexus are certain macroscopic ganglia, namely the semilunar ganglia flanking the origin of the coeliac artery, the aortico-renal ganglia about the origin of the renal arteries, and the superior mesenteric ganglia at the origin of the superior mesenteric artery. These named ganglia are all interlinked, and are not to be regarded strictly as separate entities. Further, joining this plexus are the vagal fibres derived from the posterior vagal trunk. The branches are distributed in the form of perivascular extensions accompanying the arteries arising in the vicinity. The following are the branches accompanying the coeliac axis artery.

Left gastric

(i) The left gastric plexus supplies branches to the lowest part of the oesophagus and the adjacent portion of the stomach.

Hepatic

(ii) The hepatic plexus supplies branches to liver, gall-bladder, stomach, duodenum and pancreas.

Splenic

(iii) The splenic plexus sends offshoots to the spleen, pancreas and stomach.

Phrenic

(iv) The phrenic plexus accompanies the inferior phrenic artery and is distributed to the diaphragm, suprarenal plexus, inferior vena cava and the oesophagus.

Suprarenal

(v) The suprarenal plexus is large and is derived widely from the coeliac plexus as well as directly from the splanchnic nerves. Some of the fibres are to be regarded in this case as pre-ganglionic sympathetic neurones for distribution to the medulla of the suprarenal gland; developmentally considered, the medullary cells of the suprarenal gland are equivalent to post-ganglionic neurones.

Renal

(vi) The renal plexus is derived, in the main, from the aortico-renal ganglion and from the lowest splanchnic nerve when this is present. It extends along the renal vessels to the hilum of the kidney.

Testicular and ovarian

(vii) The testicular and ovarian plexuses are offshoots of the coeliac plexus in the region of the aortico-renal ganglion. Each accompanies its corresponding testicular or ovarian vessels: the testicular plexus supplies the spermatic cord, epididymis and testis; the ovarian plexus supplies the ovary, broad ligament and uterine tube and ends in communication with the uterine plexus (derived from the pelvic plexus).

Superior mesenteric

(viii) The superior mesenteric plexus accompanies the superior mesenteric artery and its branches and so reaches the gut between the layers of the mesentery. In this manner, both sympathetic and parasympathetic nerves reach the small intestine, caecum and colon as far as the splenic flexure.

Abdominal aortic

(ix) The abdominal aortic plexus—variously named "aortic plexus", "pre-aortic plexus" and "intermesenteric nerves"—must be regarded as the counterpart of the superior mesenteric plexus but destined for more distal parts of the intestine. The nerve strands running downwards from the coeliac plexus in front of the aorta are reinforced near the origin of the inferior mesenteric artery by visceral branches of the upper two lumbar ganglia. The plexus is

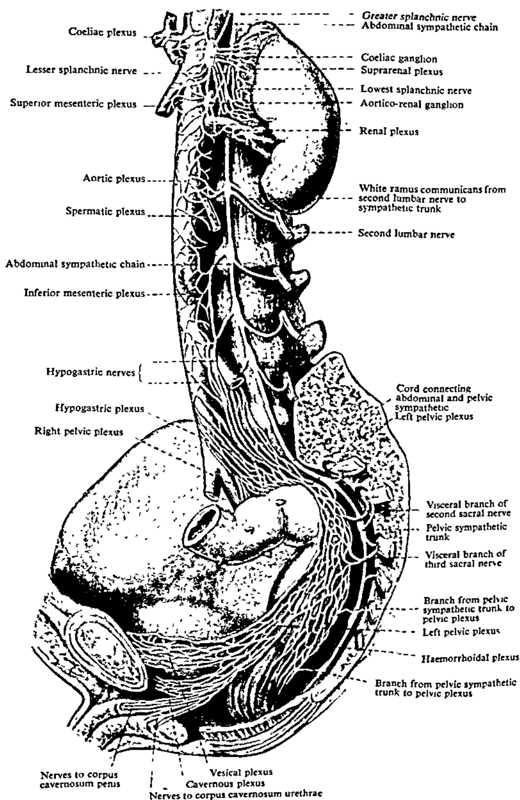


FIG. 216.—The plexuses of the autonomic system in the abdomen and the pelvis.

distributed in two parts: the perivascular plexus accompanying the inferior mesenteric artery, and the extension which descends farther caudally to join the hypogastric plexus.

Inferior mesenteric

(x) The inferior mesenteric plexus is composed of sympathetic contributions from the coeliac plexus and the upper two lumbar ganglia as well as of certain components ascending from the sacral parasympathetic nerves. Offshoots accompany all the branches of the artery and are distributed to the descending colon, pelvic colon and upper part of the rectum. There is no macroscopic inferior mesenteric ganglion in man.

(4) The hypogastric plexus

Main components

This has two main components. (a) From the pre-aortic plexus there is a caudal continuation over the aortic bifurcation in the form of several strands of fibres. (b) Visceral branches from the upper two lumbar ganglia join the pre-aortic plexus near the origin of the inferior mesenteric artery, and run down with it to enter the hypogastric plexus, while from the lower two lumbar ganglia, branches run directly to the plexus. The branch from the third ganglion passes between the common iliac artery and vein, and that from the fourth, behind both. There is thus formed a plexiform mass of fibres and interposed ganglion cells occupying the interval between the common iliac vessels, and lying in front of the body of the fifth lumbar vertebra. The commonly employed surgical name, "presacral" nerve, is therefore misleading. It is generally plexiform but may be condensed into a few strands. It represents the downward continuation of the abdominal plexuses into the pelvic region.

(5) Pelvic plexuses

The pelvic plexuses lie embedded in the connective tissues which occupy the interval between the viscera and the lateral pelvic wall. Small aggregations of ganglion cells are found amidst the plexuses. Entering each pelvic plexus are three sets of fibres: (a) the corresponding half of the hypogastric plexus which descends beside the rectum to reach the postero-superior part of the pelvic plexus; this is a sympathetic contribution and forms the bulk of the pelvic plexus; (b) the second and third sacral ganglia of the sympathetic chain provide a minor group of fibres; (c) the sacral parasympathetic nerves (nervi erigentes) from the second and the third or third and fourth sacral nerves also enter the plexus. Extensions from the plexus proceed to various organs which occupy the pelvis and the perineum and some recurrent branches (parasympathetic) ascend to reach the inferior mesenteric plexus.

The sympathetic and parasympathetic elements of the pelvic plexus are distributed in the following way:

(a) Rectal

This supplies the wall of the rectum and of the anal canal where it is joined by a continuation of the inferior mesenteric plexus, and some few direct rectal branches from the sacral sympathetic chain.

(b) Vesical

The vesical plexus is the forward extension from the anterior part of the pelvic plexus and supplies branches to the bladder, the terminal part of the ureter, the seminal vesicle and the vas deferens.

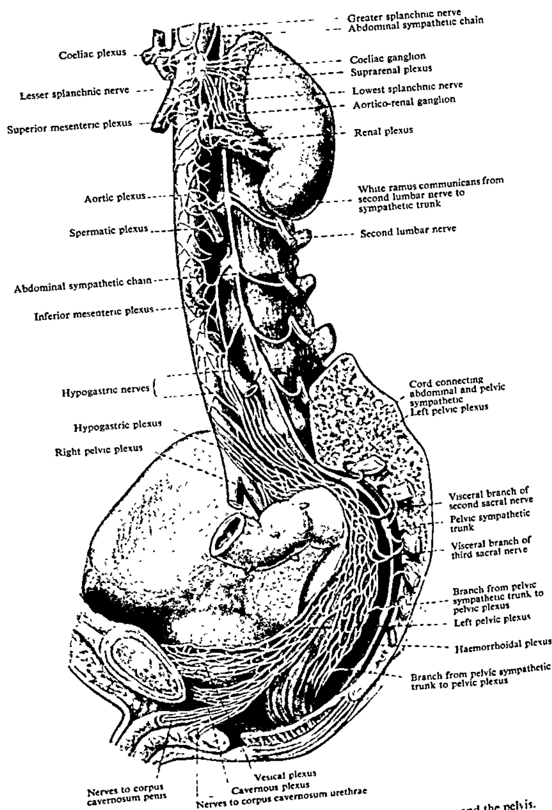


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plexus and supplies branches to the bladder, the terminal part of the
, the seminal vesicle and the vas deferens.

(*c*) *Prostatic*

This supplies the prostate, the prostatic and membranous urethra and the seminal vesicle.

(*d*) *Uterine*

This accompanies the uterine artery; its lower branches are distributed to the cervix and isthmus; longer branches ascend to the corpus uteri, the fundus and the Fallopian (uterine) tube.

(*e*) *Vaginal*

The vaginal plexus is formed mainly from the visceral branches (parasympathetic) of the sacral nerves entering the pelvic plexus. It supplies the walls of the vagina and the urethra.

(*f*) *Cavernous*

In the male, extensions from the prostatic plexus reach the erectile tissues of the penis; in the female, similar nerves proceed to the clitoris from the vaginal plexus. It is suggested that the internal pudendal nerve also carries autonomic fibres, both sympathetic and parasympathetic, to the penis or the clitoris.

4. THE PARASYMPATHETIC SYSTEM

Cranial division

The oculomotor (III), the facial (VII), the glossopharyngeal (IX) and the vagus (X) nerves all contain parasympathetic fibres the distribution of which is briefly outlined below.

(*a*) *Oculomotor nerve*

Pupillo-constrictor fibres

The parasympathetic fibres in the third cranial nerve have their cell station in the ciliary ganglion in the orbit from which they proceed to the eye as short ciliary nerves. Within the eyeball they supply the ciliary muscle (accommodation) and the sphincter pupillae muscle (pupillo-constriction).

(*b*) *Facial nerve*

Secretory nerves to salivary glands

The sensory root of this nerve carries parasympathetic fibres for distribution to the sphenopalatine and the submandibular ganglia. From the former, post-ganglionic fibres are distributed along branches of the maxillary nerve to the glands of the nose and the palate and to the lacrimal gland. From the submandibular ganglion fibres proceed to the submandibular, sublingual and lingual glands as their secreto-motor supply.

(*c*) *Glossopharyngeal nerve*

Sino-carotid nerve

The parasympathetic fibres of this nerve have their synapses in the otic ganglion from which the post-ganglionic fibres proceed via the auriculo-temporal nerve to the parotid gland. Among the sensory fibres in the glossopharyngeal nerve is an important group carrying vasosensory impulses from the carotid sinus and the carotid body (sino-carotid nerve).

(*d*) *Vagus nerve*

The vagus nerve is composed of various types of fibres, which include a large number of splanchnic efferent (parasympathetic) fibres and also many splanchnic afferent fibres. The parasympathetic efferent fibres run either to diffuse plexuses, such as the cardiac plexus, or to ganglion cells in the walls of the viscera supplied. The chief fields of distribution are the heart and the alimentary and respiratory systems. In general, the various branches of the vagus

nerve in both the thorax and the abdomen become intimately associated with sympathetic fibres, and by dissection it is quite impossible to unravel the two sets ; functionally, however, each retains its individuality, and acts differently on a particular viscus.

Alimentary system

In the alimentary system the various branches—oesophageal, gastric and intestinal—derived from the vagus nerves provide the nervous pathway for impulses controlling motility of the gut and the onward movement of its contents. Secreto-motor fibres induce secretion of the associated glands; other fibres are inhibitory to sphincters, for example the pyloric and the ileo-caecal. Such branches extend as far as the transverse colon, after which the sacral parasympathetic system takes over.

Respiratory system

In the respiratory system the vagus nerve induces bronchoconstriction, and in the heart, deceleration.

Vagal afferent fibres

A great many of the splanchnic afferent fibres in the vagus nerve are "silent" afferent fibres in that they generally give rise to no reaction in consciousness, but others—for instance from the pharynx and the larynx and, to a less extent, from the oesophagus—provoke obvious conscious states and also provide the afferent side of reflex mechanisms such as coughing. Still other fibres from vessels provide the afferent side of important cardiovascular reflexes; for example, from the aortic arch and its associated glomus aorticum, vasosensory impulses are conveyed by the vagus nerve to the medulla. All the various afferent fibres have their cell bodies located in the vagal ganglia.

The detailed course of the vagus nerve through the neck and thorax need not be reviewed here, but a brief account of the various plexuses associated with the nerve is given. In the thorax there are pulmonary, cardiac and oesophageal vagal plexuses. The pulmonary and cardiac plexuses are not distinct entities. The former are composed of intermingled collections of ganglion cells and nerve fibres situated partly in front of, but mainly behind, the lung roots. The cells are predominantly vagal post-ganglionic neurones, but sympathetic fibres also traverse these plexuses. Their distribution is to the bronchial trees and the pulmonary blood-vessels as well as to the visceral pleura. Vagal activity induces bronchoconstriction and vasodilatation within the lung.

Pulmonary and cardiac plexuses

The cardiac plexuses are described as (1) superficial and (2) deep, although again these are not separate. They lie below and behind the aortic arch and receive both vagal and sympathetic supply; the cells are predominantly vagal post-ganglionic neurones. From the plexuses, fibres are distributed to the heart and coronary vessels; vagal activity induces a slowing of the heart rate and vasoconstriction, whereas sympathetic activity results in cardiac acceleration and vasodilatation.

Oesophageal plexus

The oesophageal plexus represents the continuation of the vagus nerves of both sides after the pulmonary plexuses have been formed. It descends about the oesophagus, supplying it and adjacent structures, for instance the pericardium. Close to the diaphragm, two vagal trunks (anterior and posterior) arise from the plexus and enter the abdominal cavity with the oesophagus. They then lie in front of and behind the stomach as anterior and posterior gastric nerves. Apart from distribution to the stomach itself, supply is sent to the liver and the gall-bladder and communication is made with the coeliac plexus (from the posterior gastric nerve). Along this latter route distribution

is effected, in the same way as for sympathetic fibres, to the greater part of the abdominal alimentary canal.

5. SACRAL PARASYMPATHETIC SYSTEM

This system arises in several delicate nerves from the anterior primary rami of the second and third or the third and fourth sacral nerves. Their cells of origin lie in the sacral part of the spinal cord and therefore they will have had a considerable course in the cauda equina before they appear in the pelvis.

Pelvic splanchnic nerves

These two or three strands, known as the pelvic splanchnics or nervi erigentes, are composed of medullated pre-ganglionic fibres (comparable, therefore, with white rami communicantes) which proceed to the pelvic plexuses in association with sympathetic fibres. They meet their post-ganglionic neurones either in these plexuses or in the walls of the viscera which they supply—namely the distal colon and the rectum—and in the terminal or pelvic parts of the urogenital system. Further details of the course of the fibres concerned are given in the account of the sympathetic system in the pelvis. (*See* p. 461.)

The sacral parasympathetic system takes over from the vagus, probably in the region of the descending colon, and is concerned with the emptying mechanisms of the various hollow viscera—rectum, uterus and bladder—as well as with the phenomenon of erection (vasodilatation) of the genital organs and the neuromuscular control of ejaculation.

6. AUTONOMIC INNERVATION OF LIMBS

(1) Upper limb

The pre-ganglionic neurones are located in the lateral grey column of the spinal cord and emerge in the ventral roots of the third to the seventh (or lower) thoracic nerves; from here they pass, as white rami communicantes, to the sympathetic trunk. The first thoracic segment does not contain arm pre-ganglionic fibres, and the second appears to be most often devoid of them.

Pre-ganglionic fibres

These fibres pass up the sympathetic trunk and have their synapses in the inferior cervical ganglion and, to a lesser extent, in the middle cervical ganglion. Grey rami pass to the component roots of the brachial plexus. Some additional fibres may reach the roots from the periarterial plexus surrounding the vertebral artery.

Post-ganglionic fibres

In the limb these fibres are distributed with the various nerves and are, in general, responsible for vasomotor, sudomotor and pilomotor effects. Only the proximal parts of vessels are supplied direct from the sympathetic trunk; from the axillary artery downwards the vasomotor supply is derived from branches of the limb nerves, that is, by fibres which have originally been grey rami communicantes.

(2) Lower limb

In the case of the lower limb the cell bodies of the pre-ganglionic fibres lie in the cord at about the levels of from the tenth thoracic to the third lumbar segments, and the fibres emerge in the ventral roots between the tenth thoracic and the second lumbar. There appears to be some variation in the levels of emergence of the pre-ganglionic fibres for the lower limb. In the sympathetic trunk the fibres descend and, after having their synapses in the lower lumbar

and upper sacral ganglia (from the third lumbar to the third sacral segment), the post-ganglionic neurones are distributed as grey rami communicantes to nerves comprising the lumbo-sacral plexuses. Thereafter their distribution is *much the same as is that of the comparable fibres of the upper limb.*

7. INNERVATION OF BLADDER AND RECTUM

Three sets of fibres are concerned in the innervation of the pelvic structures. The pudendal nerve—a somatic nerve—contains efferent and afferent fibres connected to the cord by the third and fourth sacral roots. The motor innervation of the striped urethral sphincter and the external anal sphincter is mediated by the pudendal nerve. Afferent fibres are concerned with the innervation of the posterior urethra and of the anal canal.

Pudendal nerve

Sympathetic nerves are derived from the levels of the first and second lumbar segments, and reach the pelvis via the hypogastric plexus and the inferior mesenteric plexus. The post-ganglionic neurones of this group are distributed to the rectum and to the smooth musculature about the trigone and the urethra. Afferent fibres return to the lower thoracic and the upper lumbar cord from corresponding parts of the viscera.

Sympathetic nerves

The parasympathetic fibres emerge from the cord in the second and third or the third and fourth sacral segments and, after synapses in the pelvic plexus, are distributed to the expulsive musculature of the bladder and the rectum and are concerned in the relaxation of the smooth sphincters of the urethra and the anus.

Parasympathetic fibres

It is suggested that painful vesical impulses are mediated by the afferent fibres accompanying the sympathetic nerves, while the important proprioceptive afferent fibres, normally aroused by the stretching of the wall during the filling of the bladder or the rectum, accompany the parasympathetic nerves to the sacral cord.

The parasympathetic system would appear to be of greater importance in the acts of micturition and defaecation, but it is suggested that the sympathetic system plays the greater part in seminal ejaculation; in the latter case this system brings about contraction of the seminal vesicles and leads to inhibition of the expulsive (detrusor) musculature of the bladder and to contraction of the smooth sphincter of the latter. During ejaculation, therefore, micturition is inhibited and reflex of seminal fluid into the bladder is prevented.

[References to other titles are given under Autonomic Nervous System in the Index Volume. The subject of Sympathetic and Parasympathetic Nervous System is also dealt with in the *British Encyclopaedia of Medical Practice* (1938), Vol. 11, p. 503.]

AUTONOMIC NERVOUS SYSTEM: ARTERIES

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1. VASOMOTOR CONTROL OF ARTERIES

45.] This article deals with the commoner diseases of the arteries and with the results which may be expected from operations on the autonomic nervous system in the treatment of these diseases.

In the present state of our knowledge the subject is necessarily limited almost entirely to the treatment of disease in the vessels of the extremities. The cerebral and visceral arteries must as yet be regarded as outside the range of autonomic surgery. Our knowledge of the control of the cerebral circulation is scanty; section of the cervical sympathetic trunk produces no obvious clinical effect on it, no dilatation of the retinal arteries is seen and, in fact, no perivascular plexus can be demonstrated on these vessels. Of the larger visceral arteries only the renal and the mesenteric arteries have been subjected to sympathetic denervation, and this only in a few instances.

The alterations of rest and functional activity demand variations in the blood supply which are provided in part by alterations in the calibre of the vessels. This control is carried out by the autonomic nervous system, and also to a considerable extent by independent action of the smooth muscle of the tunica media. The method by which control is exercised by the autonomic nervous system is not fully understood. There can be no doubt of the existence of vasoconstrictor fibres; their course and function are well known. There is strong clinical and experimental evidence for the existence of vasodilator fibres, but the method by which vasodilatation is brought about is not clear. These fibres have not as yet been subjected to any planned surgical intervention; our operations are at present confined to interruption of the vasoconstrictor mechanism. The site of this interruption is preferably preganglionic. For the arm the section is below the stellate ganglion; for the leg the customary section of the lumbar trunk is pre-ganglionic for most of the arteries of the leg, the vasomotor neurones of which have their synapses in the sacral ganglia.

Control of vessels

There can be no doubt that an important share in the control is taken by activity of the tunica media, even when deprived of its nerve fibres, in response to blood-borne chemical stimuli. For instance, within five or six days the skin of the sympathetically denervated limb will lose much of its warmth and colour because of a considerable return of muscular tone in the arteries. This fact is very important because it explains why there is some degree of incompleteness or "relapse" in certain cases after the operation of sympathectomy.

Occlusion and spasm

With few exceptions the arterial diseases which call for surgery are occlusive in nature; they produce obstruction and ischaemia either by spasm or by structural narrowing of the arterial lumen. Such a division into (1) spasm and (2) organic obstruction can never be absolute, however, for in practice these two pathological states often coexist. For example, repeated severe attacks of spasm, such as occur in the Raynaud syndrome, in poisoning by ergot, and in some cases of cervical rib, will cause organic obstruction by inducing thrombosis. On the other hand, organic obstructions, as in thrombo-angiitis obliterans and arteriosclerosis, not infrequently show an element of spasm, especially in the earlier stages.

Objects of sympathectomy

The object of operations on the autonomic system is therefore twofold: first to abolish or at least diminish spasm by destruction of the vasoconstrictor mechanism and secondly to improve the circulation by dilating collateral channels. This latter object must always be subject to the proviso that these possible collateral vessels are neither too thrombosed nor too grossly altered in structure. It is to this increased blood supply that the dramatic relief of pain which sometimes arises after sympathectomy is to be attributed. Further, it must always be remembered that the immediate effect of sympathectomy is likely to be reduced by the quick return of tone in the muscle of the arterial wall. A further consideration is that we are seldom fortunate enough to be dealing directly with the cause of the disease. Our operations depend for their success mainly upon providing alternative channels and, however encouraging the results are in some cases, the original disease is likely to persist and to run its course unchecked by our intervention.

2. PROGRESSIVE ARTERIAL OBSTRUCTION

(1) Clinical history

The first effect of the ischaemia is coldness of the extremities. Few patients are observant enough to trouble about this, and their first complaint is usually one of intermittent claudication. This severe and arresting cramp-like pain, usually in the calf but occasionally in the sole of the foot, becomes slowly but steadily worse and the walking distance is more and more restricted. After a time there develops a characteristic brick-red rubor of the toes when the limb is in the dependent position. Not long after this there occurs a "rest" pain which is quite distinct from the "exercise" pain of claudication. It is worse at night, in the recumbent position and when the patient is warm in bed; smarting and burning in type, it interferes with sleep and does much to reduce the patient's well-being. The rubor extends in area and darkens in hue, passing almost insensibly into a persistent and deepening cyanosis. The final stage is the onset of gangrene, sometimes preceded by tedious ulcers and onychia.

Claudication

Rubor

Pain

(2) Clinical examination

With the limb stripped and in a dependent position examine it for colour, surface temperature and pulses. If rubor is present it is evidence of a considerable degree of obstruction. Allow it to develop to its full extent and quickly elevate the limb above the heart level. If rubor develops quickly and on elevation blanches rapidly, the impairment of the arterial supply must be regarded as serious. This test is of the greatest value. If after noticing the colour of the feet at rest the patient is made to walk a short distance, the feet may be found to be of a cadaveric whiteness. The change is not due to spasm but arises simply from the fact that during muscular action the veins have carried off the blood more quickly than it can be replaced by the choked arteries.

Colour tests

Persistent cyanosis unaffected by warmth or position is ominous of impending gangrene.

Pulse

The presence and strength of pulses in the normal positions give some indication of the state of the circulation, but yield no information whatever as to the state of the more distal circulation. Moreover, a slight amount of thickening or oedema will easily mask a normal pulse.

The nature and position of ulceration or onychia should be noted. Circulatory insufficiency should always be suspected as a cause of a chronic onychia, especially of the great toe. Attention should be paid to the state of the nails; their condition is a good indication of the state of the vascularity of the nail bed.

Pain

Inquiry should be made into the character and site of pain, whether exercise or rest pain, and whether exposure to cold air and assumption of the dependent position afford relief, such as is commonly found in the more severe cases of arterial obstruction.

Phlebitis migrans

Evidence of patches of phlebitis migrans should be sought. These seldom take the form of the more common inflamed cord, but are usually seen as multiple small tender bright-red patches which appear from time to time about the sole of the foot or just above the ankle. They cause little trouble

and tend to clear up within three weeks but are very significant in any case suspected to be one of thrombo-angiitis obliterans.

Fine fibrillary tremors in the sole muscles are indicative of a deficient blood supply.

Sweating

The presence of visible sweat should be noted. Sweat in amount may indicate some cause of irritation which is involving sudomotor fibres, but the slighter degrees of sweating may be ignored; they usually mean no more than a skin so cold that a normal perspiration fails to evaporate.

A thorough examination of the patient should be made in all cases. For instance, it may disclose a background in patients suffering from the Raynaud syndrome and it will throw a light on the general condition of the cardio-vascular system when arteriosclerosis is suspected.

(3) Tests of circulatory efficiency

Recording of temperature

The recording of temperature before and after temporary paralysis of the sympathetic fibres is the most exact and informative of all diagnostic measures. A thermo-couple thermometer provided with eight or ten leads is advisable and for very exact work a constant-temperature room is essential. The patient lies with the limbs under examination stripped and fully exposed with the leads lightly strapped to the digits; several observations are taken during half an hour. A spinal anaesthetic, which should reach to at least the fourth costal interspace, is given, or in the case of an arm, injection of 2 per cent procaine hydrochloride is made into the neighbourhood of the stellate ganglion.

Tests by spinal anaesthesia

Injection of the ulnar nerve at the elbow or of the median nerve above the wrist may be done instead of the paravertebral injection. Several readings of the temperature are taken and should, if some measure of vasodilatation has been obtained, show a distinct rise. The rise obtained in the foot of a young healthy subject after spinal anaesthesia is of the order of 8–10° C. In the presence of arterial disease the rise is much less, but a gain of 1–2° C. would indicate that a sympathectomy should be worth while. The value of the method lies in the fact that it does for an hour or two exactly what one hopes to obtain permanently by operation.

Tests by raising the body temperature

Tests which depend upon the raising of the body temperature by the injection of foreign protein, for example typhoid vaccine or muscle extracts, are not practised nowadays to any extent. The indications obtained are not very reliable, and the method is apt to cause much constitutional disturbance and on occasion has proved to be disastrous to the limb. A safer method, which is of value in research work, is to submit the body to heat in a wooden cabinet with apertures through which the extremities can be exposed to the temperature of the room and their readings taken by thermometer.

The claudicometer

The instrument known as the ergograph or claudicometer will often give useful evidence concerning the circulatory efficiency of a limb. The machine is made in various types which all work on the same principle. A group of muscles, for example the plantar flexors of the ankle, is used to lift a weight of five pounds through a fixed distance with a regular action of thirty strokes per minute, checked by a metronome. After the patient has worked the machine for a short time the limb may be seen to blanch and complaint is made of a pain which quickly increases and, finally, stops the movements. In this way a

fairly accurate quantitative idea is obtained of the value of the circulation. Figures of forty strokes or under indicate grave arterial obstruction. Arterial disease of the extremities is usually bilateral but is commonly different in severity on the two sides. This method can give information concerning the condition of the contralateral limb about which, although it is diseased, the patient may make no complaint because the more severely affected limb always stops him before symptoms can develop in the other. The method is further of value in separating cases in which lameness is due to a non-vascular condition, for example neuritis or fibrositis.

The oscillometer

Some form of oscillometer based on the original Pachon type is often used. It may elicit pulsations too slight for detection by other means, but its quantitative value is small and it is too easily at the mercy of the operator.

Arteriography

Although with modern technique the practice of arteriography is safer than it was, this method should not be adopted as a routine procedure. In cases of obstruction from disease its interest is largely academic and it is seldom that the information is more than can be obtained by careful clinical examination. It is, however, of more value in injury, and may help in problems such as the size and extent of traumatic aneurysms, the position and nature of arterio-venous fistulae and the extent to which a collateral circulation has been established.

Skiagram

A skiagram is often advisable; it should be of low penetration to give good shadows of soft parts, and it is chiefly of use for the discovery of patches of calcification in patients suspected of having arteriosclerosis. The skiagram may show areas of calcinosis or of osteoporosis in the Raynaud syndrome.

Tourniquet

The tourniquet test of Moschcowitz may be tried. It consists in noting the extent and rapidity of development of an area of reactionary hyperaemia after the release of a tourniquet which has been applied for five minutes. It has been used chiefly as a guide to the level at which amputation may safely be done, but its indications cannot be regarded as generally reliable.

Capillary microscopy

By the use of a microscope with a low-power objective and a drop of cedar-wood oil on the skin, a good view of the capillaries can be obtained. It is, however, difficult to establish a norm, and the changes seen in disease are variable and are not easy to interpret. It is possible that with further experience the method may prove to be of value.

Plethysmography

The method of estimating circulatory efficiency by using a plethysmograph to record variations in volume belongs rather to the research laboratory than to the ward or the theatre.

Criticism of tests

A general comment may be made here that most of the above tests give data only on the colour and temperature of the skin, but give no direct information on the state of the blood supply to muscle. It is clear that a muscle in action calls for an amount of blood greatly in excess of that needed to raise the temperature of the skin, and therefore the warming up of skin gives no guide to the probable effect of sympathectomy on claudication.

3. OPERATIVE PROCEDURES

(1) Paravertebral injections of the trunk

These comprise either injections of 2 per cent procaine hydrochloride in order to produce temporary interruption or of 95 per cent alcohol so as to cause

permanent paralysis. The injection of alcohol may be followed by a severe and persistent neuritis and this method should not be regarded as a substitute for open operation. Exceptionally, the risk may be considered justifiable in certain cases, for instance in angina pectoris in which the patient's condition may not be thought good enough to warrant the major procedure.

Caution in use of alcohol

(*a*) *Upper thoracic region*

For an account of this procedure *see* p. 259.

(*b*) *Lumbar region*

The patient is placed on the side and the third lumbar spinous process is identified. At a point some 3 centimetres lateral to the upper limit of the spinous process the needle is introduced horizontally to a depth of 4–5 centimetres, when it should strike the transverse process. Its point is then tilted slightly headwards and about 45° medially. It should pass over the upper edge of the transverse process and should be pushed on until its point can be felt to strike the vertebral body. Here the injection is made, using 5–10 cubic centimetres of the procaine hydrochloride solution. To ensure adequate blocking of the whole lumbar outflow the process should be repeated, injecting just above the transverse processes of the fourth and fifth lumbar vertebrae.

An alternative approach may be made by inserting a rather longer (12-centimetre) needle at a point 7 centimetres from the midline, inclined at an angle of about 45° to the sagittal plane, at the level of the interval between the second and third lumbar spines. The needle meets the lateral aspect of the vertebral body, and should then be withdrawn sufficiently to permit of its being reintroduced more and more anteriorly till it just makes contact with the antero-lateral aspect of the vertebral body yet can slide on past it. The needle point should be moved on one centimetre beyond the point of contact with the bone, the plunger is withdrawn to make sure a vessel has not been entered, and 30 cubic centimetres of 1 per cent procaine solution containing adrenaline are injected. This method infiltrates the tissues in which the lumbar sympathetic trunk is running; the former blocks the rami communicantes rather than the trunk.

(2) Peri-arterial sympathectomy

This operation is not now practised so often as it was in the past. Based as it is on a mistaken anatomical concept, its results are liable to be incomplete and disappointing. There are on record, however, a number of cases in which favourable results are claimed. Resort may be made to this method when for any reason the major procedures are contra-indicated. A length of artery of 4–5 centimetres is exposed under local anaesthesia, the tunica adventitia is picked up with fine forceps, and is incised in the line of the vessel. The edges are retracted and the stripping of the sheath is completed with a blunt dissector. A preliminary infiltration of normal saline under the tunica adventitia will facilitate the dissection. Some surgeons have destroyed the perivascular plexus by the injection of alcohol or by painting the vessel with phenol. Resection of a length of the artery would be equivalent to a complete perivascular operation, and this has been done by some surgeons in cases in which a thrombosed artery could be sacrificed without loss.

Criticism of the operation

Other methods

(3) Sympathetic ganglionectomy and trunk section

(a) Surgical access to upper thoracic trunk

Comparison of anterior and posterior routes

This may be by an anterior or a posterior route. The anterior route gives good access to the cervico-thoracic ganglion and the trunk below. It involves no section of bone, shock is absent and convalescence is rapid. The posterior route gives a good access to the upper part of the trunk but not always reliable approach to the ganglion, which if highly placed may be resting on the anterior surface of the roots of the first thoracic and eighth cervical nerves which lie between the operator and the ganglion. There is some shock and, since portions of two ribs are resected, recovery is slower and much more painful. After a long experience of the posterior route, I now operate entirely by the anterior route.

(b) Anterior approach

Position of patient

Anaesthesia

The patient lies on the table with the arm of the side to be operated on passed across the back as in the old classical position for ligature of the subclavian artery. Intratracheal ether by the Magill tube is the anaesthetic of choice. An incision 6–7 centimetres long is made just above and parallel to the clavicle. The external jugular vein is divided between ligatures and the lateral portion of the sternomastoid muscle is divided close to its origin. Next, the posterior belly of the omohyoid is found and divided. At this stage the operator's fingers will be able to define the taut structures of the scalenus anterior muscle. An incision should be made in the direction of the fibres through the covering of loose fat until the muscle is plainly seen. In the course of this dissection the transverse cervical artery and vein may be found and divided between ligatures. The anatomy of this artery is very variable, as indeed are all the branches of the subclavian artery, and the operator must be prepared to meet arteries and veins in unusual positions. As the surface of the scalenus anterior muscle is being cleaned the phrenic nerve will be found; it should be taped and retracted for safety. The insertion of the scalenus into the first rib is defined and, after separating the muscle from the underlying subclavian artery, it is cut across at its insertion. It is well to leave a few medial fibres for if this is done there should be no risk of injury to the thoracic duct.

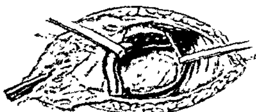


FIG. 217.—The extra-thoracic part of the anterior approach; Sibson's fascia in the floor of the wound.

The phrenic nerve

The thoracic duct

The subclavian artery is next cleaned and retracted by tape. While doing this a small branch may be seen arising from the postero-inferior surface of the artery and this may be divided and ligatured in continuity. It is the costocervical artery, and its elimination will render bloodless the operative field around the ganglion. The subclavian artery may now be retracted upwards or downwards; the former will usually give the better access to the

Retraction of the artery

supra-pleural membrane (Sibson's fascia) which is now seen on the floor of the wound (*see* Fig. 217). This membrane is thinner towards the medial side of the wound, and here it should be broken down by finger pressure. The parietal pleura comes into view and is gently stripped from the vertebral bodies and ribs.

Illumination

At this point the theatre should be darkened and a small electric bulb should be placed in the thorax (*see* Fig. 218). The head of the second rib is easily identified and the sympathetic trunk will be found at the point where it crosses the neck of the rib (*see* Fig. 219). It can often be seen, but in any case is easily reached by teasing through the overlying tissue. It is then picked up by a blunt hook and is cleaned upwards to the ganglion and downwards to a point below the third rib, cutting the afferent and the efferent rami of the third and the second ganglia. The stellate ganglion, together with the white ramus of the first thoracic nerve, is left intact. The trunk is divided below the third rib and the upper end is ligatured with fine catgut. The ligature is passed behind the subclavian artery, and is threaded on a small curved needle for the purpose of stitching the trunk into the scalenus anterior muscle with the object of avoiding regeneration (*see* Fig. 220). Exact haemostasis is essential and the wound is closed without drain.

Position of chain



FIG. 218.—Illuminator.

If the operation be a ganglionectomy the trunk is divided at the level of the second rib. Traction on the cut end will display the stellate ganglion, the resection of which is usually easy unless it is highly placed.



FIG. 219.—Illumination of the intrathoracic area.

(*c*) *Posterior approach*

Position

The patient lies face downwards with the arms dependent and the head, supported by a rest, in moderate flexion. Ether given by intratracheal tube is the best anaesthetic. An incision centred at the second rib is made parallel to the spinous processes some 3–4 centimetres lateral to them. This incision is carried down through the muscles until the posterior surface of the second rib is encountered. The approach may be by muscle splitting instead of by direct section. The ribs are best identified by the fact that the seventh cervical spinous process is on a level with the first rib, and that the tip of each spinous process gives the level of the rib below it in order. The periosteum is peeled off the rib, with due care given to the artery and the nerve at its lower border. At least 3 centimetres of the rib, together with the corresponding vertebral transverse process, are removed. The pleura is then retracted forwards and outwards with the finger and the trunk is found where it lies immediately

Anaesthetic

Identification of ribs

lateral to the heads of the ribs. According to the level of the section which the operator has in mind, it may be necessary to enlarge the field upwards by excising part of the first or downwards by removing a portion of the third rib.

Smithwick's modification

The posterior approach has been modified by Smithwick. The early stages of the operation are similar to the operation described above, except that the third rib is exposed, and the medial two inches are excised together with the transverse process of the third thoracic vertebra. The second thoracic (intercostal) nerve is found, is divided at the outer end of the incision, is traced inwards to the intervertebral foramen and finally is divided again just proximal

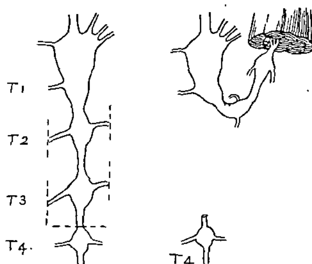


FIG. 220.—The points of section of the chain and rami are indicated by broken lines.

to the point at which the anterior and posterior roots join to form the spinal nerve. The subarachnoid space may be opened at this stage. A similar procedure is then carried out upon the third intercostal nerve. Finally, the lateral sympathetic trunk is divided below the third ganglion, all rami from the third and second ganglia—most of which must already have been destroyed—are divided, and the cut end of the trunk is embedded in the sacrospinalis muscle. The rami to the first ganglion are preserved. This radical excision of the second and third intercostal nerves from their origin to about three inches from the intervertebral foramen ensures the complete removal of the many small filaments which join the lateral trunk independently of the rami communicantes.

(*d*) *Approach to lumbar sympathetic trunk*

The two routes

The lumbar sympathetic trunk may be reached by either of two routes: (i) transperitoneal and (ii) extraperitoneal. The transperitoneal has the advantage of ease and rapidity but involves some risk of shock and post-operative distension which may give trouble in older patients. The extraperitoneal route is simple and gives good access but, since for bilateral removal two incisions are required, operation by this route may take longer. Shock and post-operative distension are seldom seen and there is little risk of incisional hernia. The extraperitoneal approach is to be recommended in the obese and in the younger patient who may have to return to hard work.

The incision

(i) *The transperitoneal approach.*—This is done under spinal anaesthesia through a long paramedian incision centred at the umbilicus, and best placed

to the right of the midline because the access to the right sympathetic trunk, lying as it does under the edge of the inferior vena cava, presents the greater difficulty. The caecum and ascending colon are retracted medially, and the posterior peritoneum is incised to the outer side of the gut (*see* Fig. 221). The psoas muscle comes at once into view and the overlying structures are easily peeled off its surface. The spermatic (or ovarian) vessels and the ureter are retracted with the peritoneum. Immediately after the ureter has been identified the vena cava comes into view. Its lateral border is defined and the trunk is sought where it lies in the groove, bounded on the medial side by the vertebral bodies and on the lateral side by the origin of the psoas (*see* Fig. 221). The trunk may be overlaid by lymphatic vessels and glands, which are sometimes enlarged and toughened by chronic sepsis in ulcerative lesions of the lower extremities; the segmental lumbar vessels usually cross in front of the trunk on this side. The trunk is identified by its pinkish-grey colour and by the presence of ganglia. Its anatomy is, however, very irregular; it may vary in size from that of a No. 20 cotton thread to that of a wax taper and, rarely, the trunk may be doubled. Consequently the resection of the trunk cannot be described in terms of ganglia but is best defined as the resection of 3–5 centimetres centred opposite the third lumbar vertebra. Section at this point involves no sexual or other disability.

The procedure on the left side is identical, save that the incision through the posterior peritoneum is in this instance lateral to the pelvic colon. This side is usually the easier, the aorta is more easily retracted, and the trunk commonly lies in front of the lumbar vessels. After resection of the trunk the viscera are carefully and exactly replaced; there is no need to suture the posterior peritoneum. During the operation digital retraction is best but if large metal retractors are used their blades should be covered by stockinet. "Packing off" is quite unnecessary and merely invites ileus.

(ii) *The extraperitoneal approach.*—The patient is placed midway between lying on his back and on his side. The upper end of the incision lies at the tip of the last rib. When the incision has reached the external

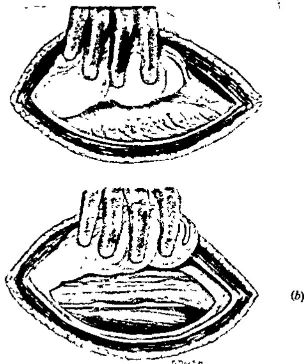


FIG. 221.—(a) Showing lines of incision of the peritoneum over psoas. (b) Below the gut, from above downwards: ureter, spermatic vessels, inferior vena cava, the ganglionated chain and psoas magnus.

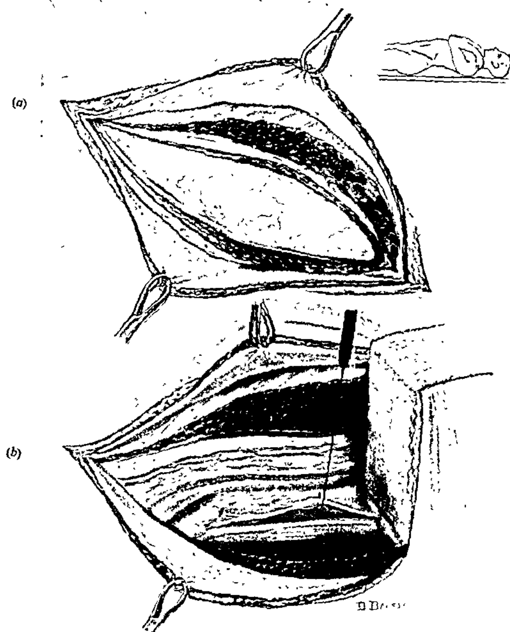


FIG. 222.—(a) The incision carried down to the peritoneum. (b) The lumbar sympathetic chain raised from its bed by a blunt hook.

oblique it is best to carry it through this muscle and the underlying internal oblique and transversus muscles until the peritoneum comes into view (*see* Fig. 222). The muscle-splitting technique does not give so good an access, and there is much risk of dividing some of the lower abdominal nerves. The separation of the peritoneum in a medial and slightly upward direction is begun at the dorsal end of the incision, the psoas is at once seen and the rest of the operation differs in no way from that by the transperitoneal approach. The muscles are sutured in layers and care is taken to ensure haemostasis.

(c) Sympathetic denervation by nerve crushing

In cases of advanced occlusive arterial disease with ulcers and much pain, White has advocated crushing of the nerves of the foot. This is carried out by incision in the lower third of the leg. The nerve or nerves which supply the painful area having been crushed, pain and vasoconstriction should be abolished for at least three months. The paralysis of the small muscles of the foot is of no account (White and Smithwick, 1942).

4. PERIPHERAL ARTERIAL DISEASES

The rest of this article is devoted to a brief description of the more common vascular disturbances of the extremities and is written solely from the standpoint of their treatment by sympathectomy. Medical and physiotherapeutic measures—often, it must be admitted, far from satisfactory—are not discussed. In order to give a realistic view of the results which may be expected I have given figures from my series of 640 interventions on the sympathetic system.

(1) The Raynaud syndrome

Definition

This term is used to describe the condition of intermittent attacks of pallor and cyanosis in the extremities. These attacks are usually induced by coldness of the body or by local cold of hands or feet. It is not strictly a disease, but is a set of symptoms which may arise from one of many different backgrounds.

Nomenclature

Raynaud's original paper (1862) contained a collection of curious cases, but out of it emerged the conception of a spasmodic lesion of the peripheral circulation, seen in young women and due to vasoconstrictor excitation. If the term, Raynaud's disease, is still to be used it should be restricted to this type. Hutchinson later pointed out that the pallor and cyanosis of digits was found in several conditions other than that described by Raynaud, and he suggested the name, Raynaud phenomenon. It may help to clarify the subject if in all forms one calls the clinical signs the Raynaud syndrome, and classifies the several types according to their respective backgrounds.

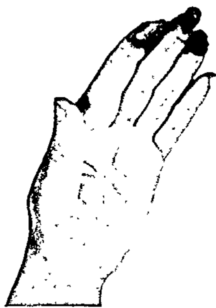


Fig. 223.—Gangrene in an old-established case of the Raynaud syndrome.

Different views on causation

The mechanism of the syndrome is not clear. Many observers hold to Raynaud's original view that the cause is an over-action of the vasoconstrictors, and the frequent association of emotions and anticipations—both pleasant and unpleasant—with the attacks, lends strong support to this view.

On the other hand, Lewis and Pickering (1934) have insisted that a primary arterial disease is the true excitant; the occurrence of the syndrome in arteriosclerosis, and after the use of vibrating tools, is in line with this theory. The problem is further complicated by the fact that repeated attacks of spasm will induce secondary degenerative changes in the vessels. It may well be that both views are right, and that in one type the syndrome may own a nervous origin but in another group may spring from local disease.

Clinical signs

In all types the attacks are intermittent with completely normal intervals. An attack usually presents the classical three stages of white, blue and red. In the white stage the fingers, less often the thumb, suddenly become white and insensitive. After a short interval this stage passes into a cyanotic phase in which the fingers are of a leaden or slaty-blue colour. Eventually the blue colour becomes mottled with salmon-pink patches "like the back of a plaice". The fusion of these patches leaves the hand for a time redder than normal. The white is the least consistent stage; it depends much upon the position of the hand and may be absent in old-established cases. Some complaint of pain is usual; a heavy ache in the white and blue stages with an unpleasant tingling in the recovery phase. Some degree of hyperhidrosis may be seen during an attack, and during the seizure the hand is useless for any exact work. The duration of an attack may vary from a few minutes to four hours.



FIG. 224.—Arterial thrombosis in the Raynaud syndrome; note the deficient circulation and osteoporosis of the terminal phalanges. Barium injection in the cadaver.

Sequelae

In many patients these attacks persist for years without further trouble or deterioration, but in more severe cases small painful ulcers form on the pulp close to the nail. In other cases patches of gangrene may be seen; these are usually superficial and are confined to the terminal phalanx. (*See* Fig. 223.) These nutritional changes are due to thrombosis of the smaller arteries, and the state of the circulation in the fingers in an advanced case is well shown in Fig. 224. Calcinosis (hypodermolithiasis) is not uncommon. (*See* Fig. 225.)

The syndrome in the feet produces similar symptoms but only rarely do they give as much trouble as in the hands. This may be due to the fact that the feet are usually covered; there is also evidence of a greater muscular tone in the arteries of the lower extremity.

In the feet

(*a*) *Types of Raynaud syndrome*

(i) *In young women.*—The commonest age of onset is round about thirty years, and in this group the emotional onset is often seen; many cases were observed during air-raid warnings. Other associations are thyrotoxicosis, anaemia and domestic or business worry. These patients often are of an unstable nervous type with a family history of migraine, asthma or epilepsy.

(ii) *In thrombo-angiitis obliterans.*—In the formidable type which begins in young men in the early twenties the first complaint is often of the Raynaud syndrome in the toes. Cases of this type run a somewhat acute course and in spite of treatment many of them will come to amputation.



FIG. 225.—Calcinosis (hypodermolithiasis).

(iii) *In arteriosclerosis.*—Attacks of a pronounced cyanotic type are sometimes seen in elderly patients, both men and women. The affected fingers are swollen and stiffened and there is complaint of much pain. Ulcers of the pulp, onychial infection and occasionally massive gangrene occur in some patients. The age of onset, usually fifty-five years and over, suggests the diagnosis, which can often be confirmed by a skiagram.

(iv) *In acrosclerosis.*—In some of the young women of group (i) there will in time—usually in the forties—develop a condition of glossy shrunken stiff contracted fingers with painful chronic ulceration of the pulp (sclerodactyly). (*See* Fig. 226.) The skin of the face, especially of the circumoral areas, is taut and mask-like and the opening of the mouth is progressively restricted. Although this grave and intractable disease is beyond doubt ushered in by the Raynaud syndrome, its developmental relation to cases in group (i) is not universally admitted; it may be a separate entity.

Sclerodactyly

Closely allied is the condition of dermatomyositis. This is found in younger men, and at its outset resembles acrosclerosis, but soon the sclerosis involves the skin over the whole body. The skin is tight and inelastic, and feels stiff and wooden; it often shows much brown pigmentation. The patient eventually dies from sclerosis of the internal organs. Although various endocrine faults have been suggested, nothing is known of the real origin of dermatomyositis. No treatment, including extensive sympathectomy which I have tried in three cases, has proved to be of any use.

Dermatomyositis

(v) *Vibrating tools.*—The Raynaud syndrome may develop in workers using

tools which are pneumatically or electrically driven at high speeds. The important factors are, a rate of over 2,000 revolutions per minute, and the hardness of the material worked. Men and women alike are affected and age appears to make no difference. The disease develops after two years of work, and when established is likely to continue even after a change of occupation.



FIG. 226.—Advanced sclerodactyly in a woman of 42 years.

Not every worker is affected but the incidence may in time reach as high as 60 per cent.

(*b*) *Treatment of the Raynaud syndrome*

Results of sympathectomy

Here and there, some exciting cause may be found, the treatment of which may abolish or alleviate the attacks. The maintenance of body warmth is important, but other measures, for example administration of calcium and arsenic, are of little use. Of recent years many cases have been treated by sympathectomy but the results are not entirely satisfactory. In the hands the immediate result is excellent but within a period of from six to eighteen months some degree of relapse is often seen. The patients, however, commonly say that the attacks are less frequent and less severe; the majority express themselves as satisfied with the result. The cause of these imperfect results is not known. They have been attributed to regeneration, and they may be due to a persistence of the original arterial disease, modified but not removed by the operation, but in some cases there is evidence that incomplete results may be due to variations in the anatomy of the sympathetic fibres.

In a series of 80 operations for the syndrome in the hands, the results are: good, 38; fair, 16; failed, 26. The length of time since operation is as much as fourteen years in some instances, but in no case is it less than two years.

The results of the operation in cases in which the syndrome is in the feet are on the contrary consistently good, and in all patients in whom disability

is severe, sympathectomy can be recommended with confidence. Of 25 cases of operation for the syndrome in the feet, all the patients remain cured with the exception of 2 in whom the relapse is distinct but trivial.

Indications for sympathectomy

(i) The majority of cases in young women are not severe enough to warrant operation, but when incapacity for work results and especially in patients with signs of early acrosclerosis operation should be performed.

(ii) In all cases in the feet of young men operation is indicated.

(iii) In elderly patients the arterial disease is usually severe with much digital thrombosis and in general operation is not worth while. It should be performed only if investigations by nerve block have yielded encouraging results.

(iv) The results are not satisfactory in established acrosclerosis with ulceration. Operation should be limited to early cases in which it may be expected to alleviate the symptoms and delay further deterioration.

(v) No records are available of results in cases of patients working with vibrating tools. In one case operated on by myself the result, after two years, was clinically incomplete but functionally worth while. Indications in this industrial type are probably identical with those of type (i).

(2) Sudden symmetrical gangrene of the extremities

This rare condition of unknown origin has been seen in young adults following severe exertion or exposure to cold. All fingers and toes and often the rims of the ears are involved but seldom is the nose. The disease begins as a sudden blanching, but spasm persists and within a few hours areas of gangrene are seen. The gangrene is confined to the terminal phalanges and, although it may look very alarming, in depth it is but slight and will eventually clear up with singularly small loss of tissue. It is, however, very painful and recovery is slow. When sympathectomy has been performed, in cases in which pain is great and recovery tedious, results have been excellent.

(3) Acrocyanosis

A tendency for the extremities, especially the hands, to become blue and cold in low temperatures is common enough, but in some patients the condition, by its persistency and severity, causes real distress and disability.

Relation to the Raynaud syndrome

Acrocyanosis is in many ways closely related to the Raynaud syndrome and is in fact, by some writers, thought to be an arteriolar spasm. Like the Raynaud syndrome it is usually seen in young women; it may begin with a transient white stage and old-standing cases may show calcinosis. Unlike the syndrome, however, the cyanosis is more persistent. There is much swelling and stiffening of the fingers, and multiple chilblains which often ulcerate are seen. In other cases there arise areas of subacute dermatitis with fissures and serous crusts. Acrocyanosis may prevent the patient from working and then sympathectomy may be advised. The results are, as one would expect, much the same as those obtained in the Raynaud syndrome. Of 7 cases in the hands 4 patients were cured, but of 9 in the feet all remain well.

(4) Perniosis

In some patients the occurrence of repeated and severe chilblains may cause disability. They are often severe on the toes and in the neighbourhood of the heel. When ulcerated and neglected they may lead to a septic arthritis of the

toe joints and occasionally amputation of a toe may be necessary. They are not usually so severe in the hands, but may be bad enough to disable workers in cold and wet occupations.

For the more severe cases sympathectomy is indicated. The results are good. Of 3 patients with perniosis of the hands and 10 of the feet all remain well.

(5) Thrombo-angiitis obliterans

Pathology

This disease of unknown origin begins as a small-celled infiltration of the muscular coat; it extends inwards causing intimal thickening and thrombosis, and extends outwards producing a peri-arteritis which mats artery, veins and nerves into one hard fibrous inextricable mass.

Sex and site

The disease occurs in men of ages from 20 to 40 years, and is extremely rare, in fact almost unknown, in women. The legs are affected first, the condition in one limb being usually more advanced than in the other; more rarely the disease appears later in the arm. Thrombo-angiitis obliterans has been described in other arteries, for instance, the spermatic and inferior mesenteric arteries, and its development in the coronary vessels is sometimes a cause of death. Mainly affected first are the tibial arteries, which may be thrombosed over considerable lengths; in some patients the blood supply to the toes is involved early.

Erratic course

Progress of the disease is very erratic; a long period of quiescence may be followed by an acute exacerbation which renders prognosis and evaluation of treatment difficult and uncertain.

Two types of lesion

There are two main types of the lesion. The one in young men of from 20 to 30 years of age is apt to run a more rapid course, has a worse prognosis and often ends in an amputation for gangrene. The other, in men of from 30 to 40 years of age is more chronic in type. It is better compensated by collateral circulation and may last a lifetime with no loss of tissue beyond that of one or two toes.

Diagnosis

If a man under 40 years of age shows signs of a chronic arterial obstruction a diagnosis of thrombo-angiitis is highly probable, but when the disease begins after 40 years of age the cause is more likely to be arteriosclerosis.

The points in favour of a diagnosis of thrombo-angiitis are the early age, the male sex, the presence of a firm fibrous thickening in the popliteal fossa and the occurrence of patches of phlebitis migrans. Such patches are found in about one-third of all the cases. A skiagram does not show calcification. The presence of the Raynaud syndrome in the feet of young men is almost certainly a forerunner of thrombo-angiitis obliterans.

Treatment

All earlier cases may with advantage be treated by lumbar sympathectomy; the later cases with rubor and threatened gangrene should be tested by spinal anaesthesia before a decision is made.

Amputation

Cases of gangrene in young men are best treated by amputation through the lower third of the thigh, but when sympathectomy has previously been performed a six-inch tibial amputation is likely to succeed. In older chronic cases partial amputation of the toes is justifiable and good healing is frequently obtained.

My results are: of 79 patients operated upon 39 were very satisfactory, 14 showed some improvement and 26 were failures.

Upper thoracic sympathectomy for the disease in the arm has produced good results. Relief of pain is marked and the patient is enabled to carry on often without loss of tissue, or at the worst with partial loss of fingers. My experience of sympathectomy in 10 patients suffering from this disease in the upper extremity is, that relief of pain and some improvement in the circulation have resulted.

Treatment in the arm

Results

(6) Arteriosclerosis

This disease is the commonest cause of disturbance of the peripheral circulation in patients of over 40 years of age. Sub-intimal thickening leads to progressive lessening of the arterial supply, and the condition may be further aggravated by attacks of spasm. The sequence of events is claudication, rubor, rest-pain, cyanosis, ulceration and finally gangrene. At what stage in this downward course can sympathectomy be of use? Unfortunately it will not cure claudication. With very few exceptions little or no improvement is seen after the operation, and it is not justifiable to hold out hope of cure of exercise-pain by sympathectomy.

Scope of sympathectomy

In the stage of rubor with rest-pain or early cyanosis, the operation is certainly worth while and has often given very satisfactory results. It should also be done in early and limited gangrene and may result in good demarcation and quick separation of a dead toe. For cases of more massive gangrene extending to several toes or to the dorsum of the foot, sympathectomy is of no use.

In some patients an acute exacerbation is seen, and is due to thrombosis on an ulcerated patch of intima or to embolism from a more proximal clot. This accident is more commonly seen in active muscular men of 50 to 60 years of age. Although arteriosclerotic, they are still capable of hard physical work, and it is usually as the result of some severe muscular effort that the disease occurs. The first sign is a sudden and very severe pain in the calf. The foot is found to be cold, numb and completely blanched. The condition rarely passes into massive gangrene, but more commonly there is a very slow improvement which may be expected to continue for several weeks as more and more collateral circulation develops. A complete return to normal is unlikely; some claudication and perhaps rubor may persist. In patients whose recovery is slow and when pain is troublesome, sympathectomy has given good results.

Symptoms

It is well to remember that serious complications may be seen at ages much younger than is generally thought (*see* Fig. 227).

Of 62 patients 40 have done very well, 10 have shown some improvement, but 12, mainly the older patients with frank gangrene, have not escaped a major amputation.

Results of treatment

(7) Anterior poliomyelitis and erythrocyanosis

In these conditions, although there is no true arterial disease, the sequelae which may be seen in both diseases are due to a relative deficiency of the arterial supply, the bulk of the limb in these patients being composed of poorly nourished fat. This is well shown in a cross-section of a limb badly damaged by anterior poliomyelitis (*see* Fig. 228).

Deficient arterial supply

In both diseases, there occur, especially in the winter, multiple subcutaneous nodules (erythema induratum). These are 1–2 centimetres in diameter, reddish-purple in colour; they itch and are tender and occur chiefly on the lower

toe joints and occasionally amputation of a toe may be necessary. They are not usually so severe in the hands, but may be bad enough to disable workers in cold and wet occupations.

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are noticeably worse at the end of a day's work. On examination it will be found that the main arteries of the arm are thrombosed. Commonly, pulsation is present in the subclavian and upper part of the axillary arteries. In fact the pulsation of the artery where it arches over the rib is so obvious that a mistaken diagnosis of aneurysm has often been made. Eventually gangrene appears in the index finger; this gangrene is deep and is likely to cause the loss of the finger.

Thrombosis

Gangrene

Some writers consider that the explanation of this striking sequence of events lies in injury to the artery where it crosses the rib. No sign of injury or deformity is found at operation, however, and it is more probable that the trouble is due to irritation of a leash of sympathetic fibres in the lowest trunk of the plexus, causing persistent spasm and so leading to thrombosis. This explanation is strongly supported by the fact that some of these patients show a profuse sweating of the affected hand. Treatment is by free removal of the cervical rib by a technique which is the same as that already described for access to the upper thoracic trunk. It is worth while to go on to the exposure of the sympathetic trunk and to crush it at the level of the second thoracic ganglion. This gives the maximal vasodilatation for a few months, after which the vasoconstrictor mechanism is restored by regeneration.

Views on causation

Treatment

(9) Erythromelalgia

This disease, originally described by Weir Mitchell, is very rare. It is entirely distinct from the painful rubor so commonly seen in ischaemia and should never be confused with it. Its basis is a condition of instability between vasoconstrictor and vasodilator mechanisms, and is best regarded as a symptom arising from various backgrounds. It occurs in young women of a nervous type. In minor forms it is not uncommon in the Raynaud syndrome, and it is to be seen in some blood diseases, especially polycythaemia vera.

Pathology

The attacks occur in the feet, seldom in the hands, and are precipitated by exercise and heat. The main complaint is of a severe burning pain, which interferes with sleep and drives the patient to keep the feet outside the bed-clothes or even to immerse them in cold water. On inspection during an attack the feet are redder than normal, veins are prominent, and the condition is exactly that seen after prolonged immersion in a hot bath. The surface temperature is slightly raised, and hyperaesthesia causes the lightest touch to be resented. In its fully developed form it is a serious disease inducing total incapacity and grave depression. Abolishing the nervous control of the vessels by sympathectomy gives excellent results. In 5 cases lumbar sympathectomy resulted in complete and permanent cure of the disease in the feet.

Symptoms

Treatment

(10) Cryopathies

Under this heading are included conditions such as immersion-foot, trench-foot, frost-bite, in fact all lesions in which the exciting trauma is cold or prolonged immersion. The pathology is damage, often grave and irreparable, to the more delicate tissue elements such as nerves and nerve endings together with the smaller vessels and capillaries.

In this section mention is made only of the later results; sympathectomy has no place in the treatment of the recent acute case. In some cases seen long after the injury the troubles are due in the main to the pronounced ischaemia.

The later cases

half of the calf, but they may be seen on the buttocks and over the tricipital area of the arm. Whereas at first they are slowly absorbed and clear up with the summer, they tend in time to become more severe, forming shallow and very obstinate ulcers, with yellow floors, which may persist all the year round.

Fat necrosis

These nodules are due to areas of fat necrosis (saponification) due to the action of cold on poorly nourished fat, and the actual cause is probably escape of lipase from the blood. Biopsy shows many large giant-cells of foreign-body type. The presence of these cells has led often to a diagnosis of tuberculosis, but repeated examinations by culture and inoculation show that this is not the case.

Results

For the more severe cases with persistent ulceration lumbar sympathectomy should be performed. It is likely to give good results up to 30 years of age, but in older patients, or in very fat limbs, the results may be disappointing. In anterior poliomyelitis the results of 56 operations are: good, 47; fair, 4; failed, 5. For erythrocyanosis, the results in 57 patients are: good, 44; fair, 6; and failed, 7.



FIG. 227.—Thrombosis of the upper part of the popliteal artery from arteriosclerosis in a man aged 32 years.

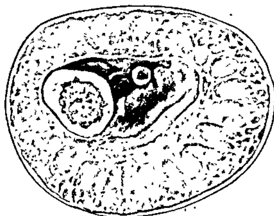


FIG. 228.—Cross section of the upper part of an adult leg; severe anterior poliomyelitis in infancy.

(8) Arterial thrombosis in cervical rib

Frequency

In all patients who suffer from symptoms due to the presence of a cervical rib some 10 per cent will ultimately develop signs of arterial thrombosis. The

First signs

first sign is persistent coldness and pallor of the hands. These signs are not intermittent like the Raynaud syndrome, but are present the whole time and

NOTE.—Upon completion of the whole work an exhaustive analytical Index will be published in a separate volume. Each individual title in this volume has been separately indexed, and its subject-matter subdivided beneath that main title; additional references and cross-references beyond this, under the name of any particular subject, have been included. No attempt has been made to include references to subject-matter appearing in this volume which is dealt with fully in future volumes, although in one or two instances it has been possible to give the volume in which this subject is appearing.

THE PUBLISHERS

INDEX TO VOLUME 1

A

The foot or hand is dusky, swollen stiff and wooden with painful chronic ulcers and the condition is, in fact, identical with the later stages of a thrombo-angiitis.

Treatment

In this type of case sympathectomy is of value and should be performed if tests by a nerve block foreshadow a good result. I have reported 5 cases in which very satisfactory results were obtained.

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[References to other titles are given under Arteries in the Index Volume. The subject of Arterial Disease and Degeneration is also dealt with in the *British Encyclopaedia of Medical Practice* (1936), Vol. 2, p. 39.]

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